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FUNDAMENTALS OF LONG-RANGE WEATHER FORECASTING

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-USSR-

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INTRODUCTION

Our scientific history contains a considerable number of attempts to reach a solution of the problem of long range weather forecasting. The following methods and approaches, which are used at the present time (individually or in conjunction with other methods)are the most common ones: 1) Statistical methods; 2) Consideration of periodicity in the changes in meteorological elements; 3) Consideration of the "peculiarities" in the course of long term curves of changes in meteorological elements; 4) Consideration of the relationship between changes in meteorological elements (phenomena) and changes in solar activity; 5) Consideration of the relationship between the formation of certain action centers and the weather in various regions of the Northern Hemisphere; 6) The establishment of the pattern of repetition and succession of the various types of atmospheric circulation; 7) The analogue method; 8) The consideration of long waves that occur in the troposphere and the consequent weather conditions on the ground; 9) The solution of hydrodynamic and thermodynamic equations of the atmosphere.

We shall briefly examine each one of these approaches and methods.

I. <u>Statistical Methods of Forecasting.</u>

The statistical methods of forecasting appeared before other methods since their application required no elaboration of the physical aspects of the interrelationships in the development of macroprocesses. Statistical methods in essence are extrapolation methods, based on the consideration of the initial condition and the tendencies.

In order to determine the initial state, various methods for representing the macroprocesses are used that permit the isolation of the more pertinent and the elimination of the unimportant features of the macroprocesses. Such determination is achieved through the compilation of conglomerate kinematic maps or maps providing average values of the meteorological elements, which was already mentioned in the preface.

Various types of statistical methods are used to determine the tendency. German meteorologists, led by Bauer, utilized multiple correlation tables for this purpose; in the United States autocorrelation methods are used in conjunction with a consideration of the normal meteorological changes during a period included in the forecast. Occasionally elementary statistical data regarding the probability of a preservation of the initial state, a change to the opposite, etc., are used.

Statistical methods also include numerous investigations for determining the correlation coefficients between the changes of one element at various points within the same region and their subsequent changes. /See Note/ Such methods were widely used by Bauer for Europe, by Wadsworth in verifying the relationships between the situation and the intensity of a series of "semi-constant action centers" and especially by Walker in his classic investigation of the relationship between weather elements on the globe and partially for the forecasting of seasonal rains in India. In the USSR this type of investigation was conducted by V. Yu. Vize as well as by a number of other scientists. A number of important characteristics involved in the circulation of the atmosphere and of its individual segments as well as certain prognostic relationships were revelaed through this method. /Note/ Such investigations also known as "world weather". One of the basic and outstanding inadequacies of all these investigations and attempts to arrive at a solution of the problem of long-range weather forecasts is the fact that the relationships established in this manner frequently do not readily lend themselves to a physical interpretation and the characteristics of their interrelationships not infrequently change with time. Therefore, a method based exclusively on these relationships may not be considered prospective. This, however, does not mean that the application of statistical relationships in combination with other, physical, methods could not be useful. Examples of their effective utilization in conjunction with a number of methods will be illustrated below.

II. Consideration of Periodicity in the Changes of Meteorological Elements.

This is one of the varieties of a statistical approach which is based on the statistical analysis of prolonged homogeneous pressure records and those /infrequently/ of temperature and precipitation at certain stations. In these cases the purpose is to establish a certain periodicity or recurrence in the variations which could then be utilized in the compilation of long range forecasts for these particular elements. Investigations have determined a great variety of different types of periods that last anywhere from several days to several decades. The methods that are used in these cases, however, such as the harmonic analysis, and smoothing not infrequently lead to an establishment of periods which do not even exist in nature. Other discovered and proven periods turn out to be unstable in time which makes it impossible to use them in prognostigation.

Weickmann's works as well as that of his successors may be included in the same group of investigations. They established so-called points of symmetry in the change of pressure on both sides of which the curve showing the dependence of pressure on time has a converse course. A group of co-workers guided by Weickmann, that is now working in Kissingen, establishes the points of symmetry not on the basis of pressure data at the different stations but on the basis of data of average pressure at several stations situated over an area of 500 square kilometers. Despite the application of the best statistical procedures in the above investigations the authors were unable to evolve a method for forecasting points of symmetry for future periods.

Bauer conducted an exhaustive statistical investigation of the possibilities for applying methods of periodicity and symmetry for the extrapolation of weather elements in order to be able to forecast them on a long-range basis. He came to the conclusion that these methods do not deserve attention or further efforts and funds as their prognostic effect does not exceed the probability of the preservation of the initial values of significance of the meteorological elements. It is apparently difficult not to agree with this conclusion.

III. Consideration of Peculiarities in the Course of Average Many Year /Normal/ Curves Depicting Changes in Meteorological Elements.

A number of investigations indicate that certain characteristics of circulation and weather found in

various regions occur more frequently on the same dates of a certain month by comparison with neighboring dates. In order to study such dependencies for a number of stations in Europe and the eastern part of the Atlantic Ocean "normal"pressure curves at sea level for a five-day period were evolved. Despite the fact that these five-day curves were evolved to cover an extensive number of years certain of their "peculiarities" did not smooth out and clearly appeared in the background of seasonal tendency. This indicates the fact that the given peculiarity as a rule occurs in individual five-day periods which were included in the averaging

A graph depicting changes in the average five-day elements of pressure for several recent months is compiled in the evolution of a prognosis of pressure for the next five-day period. This graph is entered on tracing paper and superimposed on an analogous graph of the normal course of the pressure curve. Portions of the normal curve where a coincidence of the ridges and valleys with those of the initial curve occur are also searched for in this case. Attention is usually not devoted at first to the dimensions of the curve amplitudes which subsequently is corrected by means of additional methods.

In order to find sections where the curves are parallel, it is frequently necessary to displace the curves in time. A "peculiarity" located closest to the day of prognosis is searched for on the superimposed curves. Subsequently the initial curve is extrapolated for the next five-day period more or less parallel to the normal curve.

The prognostic value of the average pressure for the next five-day period for the given station is obtained as a result. Similar operations are conducted for every station located in the region that we are concerned with in a particular case. As a result a prognostic chart of the ground level pressure for the subsequent five-day period was evolved. This approach is at the present time utilized in France and this will be described in greater detail in Chapter II, paragraph 2.

IV. Solar Activity.

Section 4 of Chapter II examined in detail the problem of solar activity and its role in the development of atmospheric processes. It indicated that the presence of such a relationship is irrevocably proven by a number of investigations. However, the mechanism

of the transfer of such interreactions from the sun to the atmosphere is not yet quite clear. It therefore follows that in elaborating methods for long-range weather forecasts, it is necessary to consider the role of this factor as well.

Chapter II also pointed out that it is incorrect to attempt to evolve a method for long-range and short-range weather forecasts on the basis of considering this factor alone. In such an approach the activity of the atmosphere is placed in complete dependence only on the external factor and the regularities that are peculiar to the atmosphere itself are not taken into consideration.

However, it is also incorrect to consider that almost all of the presently existing methods for long-range forecasting of weather even though they do recognize the concrete role of solar activity still do not take it into consideration in the compilation of forecasts not only quantitatively but qualitatively. This of course may partially be explained by the imperfect nature of our knowledge regarding the role of this factor and regarding the mechanism of the transmission of solar activities, but we also know far from everything about other factors.

It seems to us that at the present time the data yielded by observations and investigation of them provides the basis for the consideration of this factor in all methods of long-range weather forecasting, especially when the matter pertains to forecasts for a season, a year, or an epoch. At the same time it is necessary to state that in view of its exceptional complexity this problem requires an extensive program of further investigations in solar and atmospheric physics, which was already discussed in detail in Chapter II of this book.

V. Consideration of Relationships Between the State of Certain Centers of Atmospheric Activity and Weather in Individual Regions of the Northern Hemisphere.

A big step ahead by comparison with the approaches examined above was the synoptic approach which was being developed since 1913 by the Russian school headed by B. P. Mul'tanovskiy. The initial working hypothesis in this case was the following situation: the weather in a given region is a reflection of the conditions of the centers of atmospheric activity. For the prognostication of weather in the European area

of the USSR special attention was attributed to the activities of the Polar and Azores centers of activity. Subsequently it was established that the characteristics of their activity are associated with the trajectories of pressure formations, the continuity of natural synoptic periods and seasons, the occurrence and recurrence of various types of macroprocesses. The results obtained in this respect formed the basis of the synoptic method for long-range weather forecasting which, until the present time, is used in the USSR in the central institute of forecasting and which will be examined in detail in Chapter VII of this book.

Similar ideas were utilized by Elliot in the compilation of his "Type Method" which will be described in Chapter XI.

VI. <u>The Typification of Synoptic Processes</u>.

A number of investigations relating to the problem of forecasting were conducted with the goal of approaching the elaboration of methods for long-range weather forecasts based on a typification of macro-synoptic processes observed in the hemisphere or in a certain region within it. A considerable portion of such typifications was examined by us in Chapters III and IV. There it was pointed out that few of the existing typifications were developed to the point of being a method of long-range forecasting, since the regularities in the continuity of established types were not clarified in the majority of cases. The statistical characteristics of continuity, however, provided little material for forecasting as the probability of the conversion of the initial type into any one of the remaining types was frequently almost equal.

The greatest difficulty which was experienced in the utilization of types for the compilation of long-range forecasts was the forecast of the type of impending processes. The majority of errors in weather forecasts compiled on such principles evolves specifically from errors in the prognostication of the type.

The utilization of typifications in certain systems for long-range weather forecasts will be discussed in greater detail in Chapters VIII, X, XI, XII.

VII. Analogues.

In order to forecast the characteristics of an impending macroprocess it is necessary to reveal the basic effect of physical factors, their role and changes in time. Inasmuch as at the present moment to fully do this the problem is frequently solved by devious means in studying macrosynoptic processes that were observed in the past and finding processes among them that are analogous to those which are being observed in the current season, month or some other period of time. In this case it is commonly accepted to consider that as long as two seasons or months were observed to have analogous processes they were analogous physical factors that had an analogous effect and successiveness. Therefore it is considered that the further development of these initial processes will also be analogous. Then, with a certain degree of probability it is possible to assert that those processes which were observed in the analogue years during the period corresponding to the one being prognostigated will also be observed during the year covered by the prognosis under compilation.

Such an assertion of course may not be considered as proof. It is known that there are cases where insignificant differences in processes occurring in the past bring about basically different recurrences in the future. Therefore, the inevitable problem arises as to what two processes should be considered as analogous or what might be considered as a criteria for determining the analogous nature of various processes observed during different years.

Thereare many subjective views and unsolved problems in this matter. Some consider that in selecting analogues it is necessary to be limited by a similarity that occurs in certain small regions for which the prognosis is being compiled. Others consider that along with the similarities in a limited region there must also be a similarity in the selected analogues for the entire hemisphere as well. At the same time it is required that there be a similarity not only for the ground level charts but for the altitude hemisphere charts as well. Some consider that analogues may be selected on the basis of average characteristic processes. Others however prefer daily data or charts. However, if all these requirements were to be satisfied, then, having a limited number of observations [especially altitude data] it will often be almost impossible to select an analogue.

A completely new approach to the problem on the

selection and utilization of analogues was adopted by G. Ya. Vangengeym [see Chapter VIII]. The principal condition here is that in selecting analogues not the external points of similarity are considered but genetic ones, i.e. points that reflect the internal features of the development of the macroprocesses. In this case the main subject pertains to the selection of circulation homologs. [See Note] A condition that the processes under comparison must be analogous stages of more extensive processes in time and space is a condition that must be considered for this case. Such conditions are the transformation of W, C and E forms over a period of time considerably greater than periods for which the homologs are being selected. Experience indicates [see Chapter VII] that with such an approach in selection of analogues the latter may be an important auxiliary method in the compilation of long-range weather forecasts compiled on the basis of any of the existing methods.

[Note] Homolog - from the Greek word homologous - corresponding or similar in its genetic signs.

Nevertheless the compilation of a method for prognosis only on the basis of analogues may not at the present time be considered correct and therefore prospective. It is so far possible to agree with an assertion by Namias with regard to this plan on the fact that "analogues in the best case are substitutes for comprehension, and without comprehending meteorology it is hardly possible to rise beyond the low level of skill which may be attained by using the analogue method."

VIII. The Consideration of Long Waves in the Troposphere Layer and the Related Weather Conditions on the Ground.

As already indicated in the first part of this book, during the past fifteen to twenty years our knowledge on the three-dimensional structure of the general atmospheric circulation has expanded considerably. At the same time it was indicated that the processes and weather conditions observed on the basis of ground level charts are very closely associated with the structure of the thermo-pressure level of the troposphere aloft. The most important element in the chain of these associations is the long waves that are observed in altitude charts of the hemisphere and which are associated with the conditions of atmospheric centers of activity and with the characteristics of cyclonic activities in various regions

of the globe. Therefore, naturally the necessity arose for the utilization of the newly acquired data for prognostic purposes.

A number of investigations were conducted in connection with that, which had the goal of studying the causes for the occurrence, development, shifting and destruction of high altitude tropospheric waves in the hemisphere, and also to establish prognostic association between the characteristics of the waves and weather conditions at the surface.

The results of such investigations are applied in the USSR [Chapter VII, VIII, IX] and in the USA. In the USA a number of methods for long-range weather forecasting for five-day periods and for a month have been developed on that basis. These forecasts are called "physical methods" by the authors. They will be described in detail in Chapters X and XI.

The weakest aspect of this trend is the inadequate development of the problem regarding the characteristics and the speed in the evolution of the initial condition and primarily the absence of reliable prognosis regarding the high level troughs and ridges. The errors inherent in the prognosis of such new formations usually bring about serious errors in the prognosis of the rate of motion involving the troughs and ridges, and as a result in the weather changes occurring at the surface. At the present time considerable efforts of the American and English meteorologists are directed at the elimination of such errors.

Of concrete importance in the development of these trends is a more profound examination of the relationships between the field aloft and the ground weather. The so-called objective methods available at the present time [see Chapters X, XI] are still far from being able to resolve the existing problem. This apparently is one of the reasons why, despite the proven quality of the forecasts pertaining to the high level pressurefield compiled in the USA the correctness of forecasts of anomalies dropped somewhat. In connection with this Namias correctly points out that " at the present time a disproportionately large effort is expended on the perfection of the forecasting of circulation, whereas very little is being done for the interpretation of the circulation by means of the associated weather conditions.".

One of the important merits of these directions which makes them perspective is the close association

[in analysis as well as in prognostication] of regional processes with the processes taking place throughout the northern hemisphere. Such an organization of the investigations is motivated by the fact that "any system for a long-range forecast based exclusively on data that relatesto a restricted area and which does not consider reactions on a hemispheric scale must invariably be imperfect. The degree of imperfection will apparently increase in proportion with the decrease in the area involved in the preparation of the forecast. The possibilities of these methods are invariably limited by a ceiling which is very far from being perfect".

IX. Mathematical Methods.

An ideal solution for the problems of forecasting would be if it were possible to compile long range and short range weather forecasts with the assistance of mathematical computations based on a complete solution of the dynamic and thermodynamic equations of the atmosphere and if they would have such a degree of precision as those that are presently involved in the astronomic forecasts of solar eclipses. However, such a solution of the problem is associated with considerable difficulties of a purely mathematical nature as well as the difficulties associated with the absence of initial data of required precision and insufficient knowledge of the physical nature of many atmospheric processes and phenomena.

Despite all that, during the past fifteen or twenty years considerable progress has occurred in the problem being examined here which was basically possible due to the work conducted by Soviet scientists such as A. A. Fridman, N. Ye. Kochin, I. A. Kibel, and Ye. N. Blinova . The methods developed on this basis will be examined in Chapter IX.

These are the basic approaches to the solution of problems inherent in long-range weather forecasting.

Let us now move to an examination of methods for long-range weather forecasting which are applied at the present time in various countries of the world and which to a greater or lesser degree utilize the methods that were examined above in solving this very important and complex problem.

Inasmuch as in familiarizing ourselves with these methods we will have to talk of the correctness ... of the forecasts by means of those methods it will be

first of all necessary to become familiar with the basic questions of determining the effectiveness of methods and criteria involved in the evaluation of long-range forecasts. After that, basic methods which are evolved and utilized in the USSR will be examined in detail in Chapters VII, VIII and IX while Chapters X and XI will consider methods which have been developed and are used in the USA.

Chapter XII will provide a brief survey of investigations and the problems and methods being examined which exist in individual countries of the world in order to establish a better understanding of the contemporary state of this problem and of the methods involved in its solution.

* * *

CHAPTER VIII

THE MACROCIRCULATION METHOD OF LONG RANGE HYDROMETEOROLOGICAL FORECASTS ACCORDING TO

G. YA. VANGENGEYM

I. Initial Principles.

The initial principles in compiling a method are as follows: (1) Physical regularities in the development of general atmospheric circulation and not partial associations of a statistical nature or dependence established on the basis of data for restricted regions that are dis-associated with the processes in the other regions of the hemisphere, must form the basis of long range weather forecasts for any region. Therefore an analysis and a forecast must be evolved through a broad utilization of both ground level and high altitude charts of the entire globe or at least of the entire northern hemisphere. (2) In actual circumstances a general circulation of the atmosphere is always represented in terms of its concrete forms. Therefore, in a prognostic sense, it is very important to show these forms and to establish regularities in its changes. Processes of the W, C, and E, established by G. Ya. Vangengeym in 1939 and carefully examined in the first part of his book (paragraph 1, Chapter 3) may be utilized as such forms. (3) The forms of atmospheric circulation and the continuity in their changes being observed during a given season regularly arise as a result of the development of forms that were observed in the preceding seasons. Therefore, in order to evolve a method for seasonal forecasts and in compiling such forecasts it is necessary to conduct a multilateral examination of the development of processes involved in the general circulation of the atmosphere in the preceding period of time (covering at least a 4 to 5 month term). At the same time it is quite necessary to reveal both the forms of progressive development (fresh evolutions) as well as the degenerating forms which reflect features that were observed in the processes occurring in seasons that preceded the current season. (4) Beside the regularities in the continuity of the W, C, and E, forms, in the compilation of long range weather forecasts it is necessary to utilize, as an auxiliary method, the analogues of the processes of circulation that occurred in the past years, which permit the consideration of an over-all effect of

the interacting factors. However, it is necessary to select analogues not by their external similarities but by their genetic similarities, i.e. according to features that reflect internal characteristics in the development of the macroprocesses. Therefore, the matter at hand here is the selection of circulation homologs. (5) The basis of a method for long range weather forecasts evolved a short period of time before publication must be formed by regularities in the continuity of elementary synoptic processes (E.S.P.). Inasmuch as the latter processes are stages of greater processes of the W, C, and E forms the study of regularities in their changes must be conducted in association with transformations occurring in basic forms of atmospheric circulation. It therefore follows that problems of long range weather forecasts published well in advance or on short notice must be resolved simultaneously and on the basis of the same general principal positions.

II. Method of Long Range Forecasts Covering an Extensive Period.

1. Regularities Involved in Seasonal Continuity of Forms and the Associated Weather Characteristics Over the European Territory of the USSR.

The study of the continuity in the seasonal circulation was started with winter seasons during which the processes of the W, C, or E forms received an anomalous development in January and February. All winters which had such an anomalous development involving any one of the forms such as, for instance, the W form were selected for that purpose. Then the Spring season (March, April and May) were examined in every one of the selected years and the type of circulation that received an anomalous development in every month of the season was determined.

Furthermore, all winters with an anomalous development of the easterly circulation were selected from these same numbers of years and the further development of such easterly circulations was studied. The regularities in transformations of the winter meridianal circulation were also established by an analogous method. The results of the investigations of the continuity of winter circulation are thoroughly examined in the following works:

Vangengeym, G. Ya., Opyt Primeneniya Sinopticheskikh Metodov ~~K Izucheniyu I Kharakter-~~ istike Klimata (Experience in the Application of Synoptic Methods in the Study of the

Climate and of its Characteristics), State Publishing House for Hydrometeorological Literature, Leningrad, 1935.

Vangengeym, G. Ya., Trudy GGI (Works of the State Hydrological Institute), Issue 10, 1940.

Vangengeym, G. Ya., Izvestiya AN USSR, Seriya Geograf. i Geofiz. (News of the Academy of Sciences USSR, Geographical and Geophysical Series), No. 3, 1941.

Later G. Ya. Vangengeym established regularities in the continuities of circulation from Spring (April) to the Summer, and from the Summer (July and August) to Autumn.

The table given below cites data regarding the transformations involved in circulation that occurs from season to season. The examination of that table indicates that the transformations occurring in the circulation have the following most common features: (1) Regardless of the season during which westerly circulation received an anomalous development, during the following season it has a tendency to be replaced by an easterly circulation. (2) Processes of the eastern form that received an anomalous development in any of the seasons that were examined have a tendency to become meridianal in nature by the next season. (3) Processes of the meridianal form of the initial season as a rule receive strong development during the subsequent season.

A more detailed characteristic of these transformations with the consideration of additional components and different variants may be gleaned from the following table as well as from these works. (See Table 1.)

Vangengeym, G. Ya., Izvestiya AN USSR, Seriya Geograf. i Geofiz. (News of the Academy of Sciences USSR, Geographical and Geophysical Series), No. 3, 1941.

Vangengeym, G. Ya., Trudy NIU GUGMS (Works of the Scientific Research Institutions of the Central Administration of the Hydrometeorological Service USSR), Series IV, Issue 3, 1941.

The regularities cited above were derived for use in cases where the initial season contained an anomalous development of one of the three forms of circulation. However, such cases do not encompass all types of initial seasons.

There are frequent cases also, where the two forms receive a simultaneous anomalous development in the initial season such as W. and C, W and E, or E and C. In such cases the initial season relates to combinations of W + C, W + E or E + C circulation. The successiveness of such circulation from season to season was also studied by G. Ya. Vangengeym. The results were published in the following works.

Vangengeym, G. Ya., Trudy GGI (Works of the State Hydrological Institute), Issue 10, 1940.

Vangengeym, G. Ya., Izvestiya AN USSR, Seriya Geograf. i Geofiz. (News of the Academy of Sciences USSR, Geographical and Geophysical Series), No. 3, 1941

Vangengeym, G. Ya., Trudy NIU GUGMS (Works of the Scientific Research Institutions of the Central Administration of the Hydrometeorological Service USSR), Series IV, Issue 3, 1941.

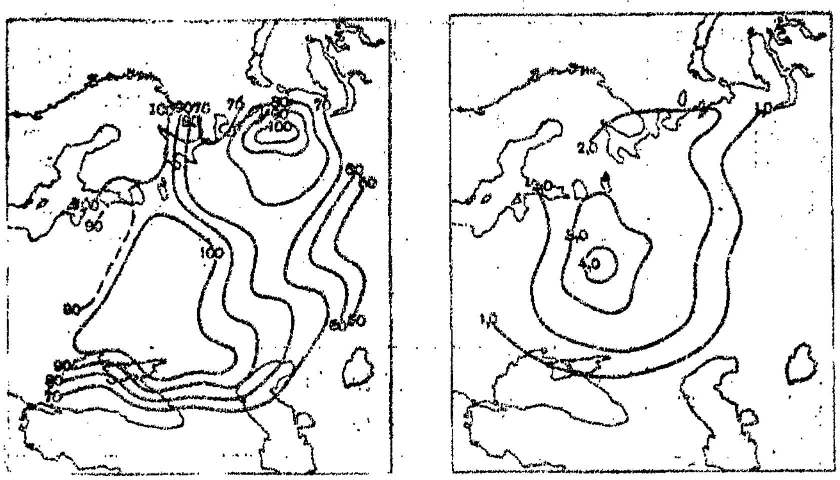
The regularities in the continuity of seasonal circulation examined above have a direct prognostic significance, as by knowing the type of circulation occurring in the initial season and utilizing the table given immediately below, it is possible to provide a forecast of the type of circulation which will receive an anomalous development during the subsequent season. This also resolves the problem of forecasting the general circulation background (macroprocess) of the forthcoming season.

It is logical to consider that with the presence of certain regularities in the development of the forms of atmospheric circulation from season to season, a regular development of certain weather characteristics must also take place, which are associated with the form of seasonal circulation that was forecast. For verifying this, as well as in order to obtain possibilities for shifting the seasonal forecast

Table 1. A Scheme of the Continuity of Basic Forms of Atmospheric Circulation From Season to Season.

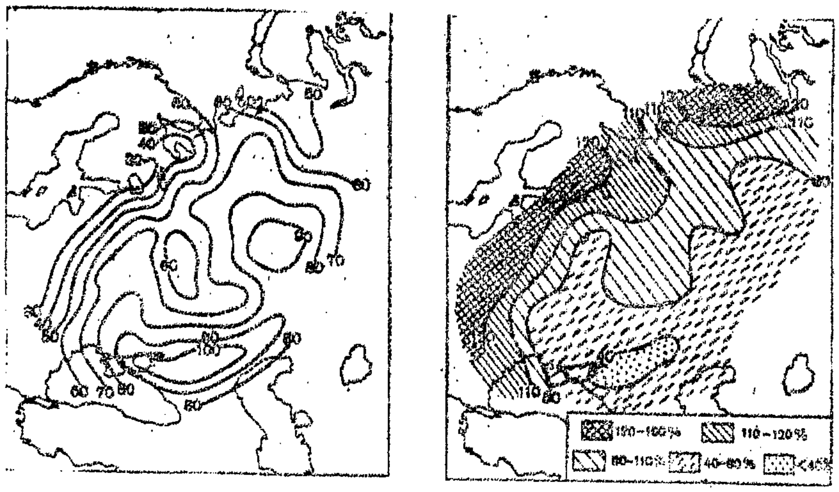
Месяцы, следующие за исходным сезоном (a)	Исходный сезон и формы циркуляции, получившие в нем аномальное развитие (b)										
	зима (январь—февраль) (c)			весна (апрель) (d)			лето (июль—август) (e)				
	W	E	C	W	E	C	W		E		C
Март (f)		C в 56% случаев (o)	C+E								
Апрель (g)	W+E	C сильно развито (p)	E+W								
Май (h)	E	E+C	чередов. C и E (q)								
Июнь (i)				J+C	C или C+W (r)	C					
Июль (j)				W+E	C+W	C					
Август (k)											
Сентябрь (l)									I вариант E+W (w)	II вариант C (x)	
Октябрь (m)							I вариант W (s)	II вариант E или E+W (t)	C	C+W или E+W (y)	W или W комб. (z)
Ноябрь (n)							E или E+W (v)	E или E+W (u)	W+C	W	C или C+E (z_1)

Legend: a. Months following the initial season; b. Initial season and the forms of circulation with an anomalous development during that season; c. Winter (Jan.-Feb.); d. Spring (April); e. Summer (July-August); f. March; g. April; h. May; i. June; j. July; k. August; l. Sept; m. October; n. November; o. C in 56% cases; p. C strongly developed; q. C & E alternating; r. C or C+W; s. I variant W; t. E or E+W; u. II variant E or E+W; v. E or E+W; w. I variant E+W; x. II variant C; y. C+W or E+W; z. W or a combination of W; z_1. C or C+W.



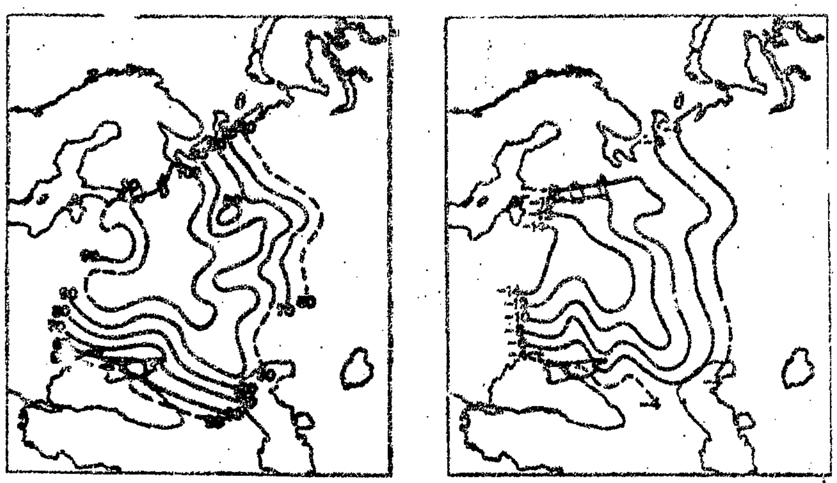
A. B.

Charts showing the probability (A) and the probable values (B) of a positive temperature anomaly during the month of April following winters with a westerly circulation.



C. D.

Probability of precipitation below norm (C) and the probable amount of precipitation (D) in April after winters with westerly circulation.



E. F.

Probability of negative deviations from the norm (E) and the probable extent of the deviation (in days) from the norm (F) for the thawing of rivers after winters with westerly circulation.

of the macroprocesses to a forecast of the weather conditions, G. Ya. Vangengeym conducted the following statistical processing of the material that he previously used for the compilation of the continuity table cited above. The nature of such processing will be illustrated on the basis of an example showing the transformations of the western winter circulation into an eastern Spring-type circulation.

During all years in which the winter was characterized by an anomalous development of westerly circulation April was, for example, studied with respect to weather characteristics observed during that month (anomalous temperature and amount of precipitation over Europe and the European territory of the USSR) as well as phenomena associated with them (thawing of rivers, the degree of freezing of the Barents Sea, and other phenomena). For that purpose the extent of the anomalies at every station was extracted from the charts depicting the anomalous temperatures occurring during every April of the selected years. After that a compilation was made of the number of instances where, for example, an anomalous temperature was observed during April at a given station, such a compilation was made for every individual station. The resulting figure was expressed in percentage of the over all number of instances and the percentage was entered on the blank by the point depicting the position of the station, after which the isograms were drawn.

A typical chart depicting the probability of a positively anomalous air temperature during April after winters with westerly circulations was derived. This chart is shown by us as chart A below.

The chart indicates that a comparatively large territory is encompassed by the 100% isogram /See Note/. The area before the 100% line indicates the possibility of negative anomalies in this area during April. Therefore those regions where the

Table 2. Average errors and the certainties of non-occurrence of errors in forecasts of river thawing beyond 20% of the amplitude of a period of many years. (1891–1938).

Десятилетия (A)	Обеспеченность прогнозов (%) (B)	Средняя погрешность прогнозов (% амплитуды) (C)
1891—1900	89	11
1901—1910	85	12
1911—1920	87	12
1921—1930	79	13
1931—1938	82	12
Среднее (D)	84	12

Legend: a. Decades; b. Certainty of forecast (%); c. Average forecast error (% of amplitude); d. Average.

Table 3. Average errors and certainties of the non-occurrence of errors and of the certainty of precipitation forecasts beyond 20% of t'e amplitude of a period of many years. (1891–1938).

Десятилетия (A)	Апрель (C)				Май (D)			
	обеспеченность прогнозов (%) (E)		средняя погрешность прогнозов (% амплитуды) (F)		обеспеченность прогнозов (%) (E)		средняя погрешность прогнозов (% амплитуды) (F)	
	методических (G)	климатологических (H)	методических (G)	климатологических (H)	методических (G)	климатологических (H)	методических (G)	климатологических (H)
1891—1900	72	62	15	21	80	61	15	16
1901—1910	80	65	13	19	72	63	15	17
1911—1920	79	53	14	21	72	59	16	20
1921—1930	78	54	15	20	78	67	13	11
Среднее (B)	77	58	14	20	76	61	15	16

Legend: a. Decades; b. Average; c. April; d. May; e. Certainty of forecasts; f. Average forecast error (% of amplitude); g. Methodical; h. Climatological.

probability of positive anomalies is less than 50%, negative anomalies are most probable. In regions located close to 50% isogram, temperatures valued close to the norm are usually observed.

/Note/ With the addition of new years this probability in certain regions may diminish somewhat, while in other regions its probability may increase.

A chart depicting the probability of precipitation below normal for April was compiled in an analogous manner (See chart C). Such a method was also used to produce a chart depicting the probability of negative deviations from the normal periods for the thawing of rivers. See charts C and D shown below. The probabilities close to 100% cover an extensive area of the European portion of the USSR on these charts as well. This objectively proves not only the presence in nature of regularities in the continuity of the W, C, and E forms that were examined above, but also the general similarity of the years that have become a part of the typical groups. In addition to providing a possibility of shifting from a seasonal forecast of the macroprocess to the forecast of weather conditions.

Therefore, using charts A --E as well as by using analogous charts for the month of May, it is possible to assert with a great degree of certainty that after winters with westerly circulation the possibility of an early and warm Spring and an early thawing of rivers in the European part of the USSR is likely. A lower level of precipitation during April in the sourthern portion and over the major part of the territory during May is also probable.

The charts that were just examined provide the possibility of compiling only a background forecast, that is a forecast providing a value of the probable anomaly. However, for practical purposes it is desirable to also have data regarding the probable degree of anomalies. In connection with that, charts showing probable degrees of the examined anomalies were compiled. They could be

drawn by averaging out the values for every given station on an individual basis for those months of April where the anomalies were positive and instances of negative anomalies separately. However, in that case, at the stations where the probability of positive anomalies, for example, is below 100%, anomalies of other values would not be reflected in the average values, whereas they could easily exist during the period covered by the forecast. Therefore, probable values of anomalies for every station were obtained as average values for all those instances that entered into a given typical group. These charts for April are shown under charts B -- F above.

We have shown charts for only one spring month, after winters with westerly circulation. Charts for April following winters with easterly circulation and winters with meridianal circulation were drawn in an analogous manner. They are all shown in the following work: Vangengeym, G. Ya., Izv. AN SSSR, Ser. Geograf. i Geofiz., (News of the Academy of Sciences USSR, Geographical and Geophysical Series), No. 3, 1941.

Such a series of charts for the European territory of the USSR were drawn for forecasting weather during summer months after springs with W, C, and E types and for the autumn months after various types of circulation occurring during the summer season as well as charts for instances of initial seasons that are characterized by a combination of circulations. This collection of charts permits the accomplishment of regular forecasts for the indicated elements and phenomena for the impending season on the basis of the form of circulation characterizing the preceding season.

In order to verify the certainty of the given method of forecasting, G. Ya. Vangengeym utilized the cited charts showing the probability and probable values for compiling forecasts for every season of the past years (1891 to 1938). The results of this verification are cited in the following two tables: (Please see tables 2 and 3 below)

From these tables it is evident that the average certainty of the errors not exceeding 20% of the many-year amplitude is 77%, in the forecasts of precipitation during April which increases the certainty of the weather forecast by 19%. The methodical effectiveness of forecasts covering the month of May is equal to 15%.

The effectiveness of forecasts for the thawing of rivers and the degree of freezing of the Barents Sea are close to these figures also.

Forecasts of temperature anomalies were verified only partially. Their certainty for April was equal to 84.8% and for May it was 77.2%.

The verification of operational forecasts for 1939 to 1942 indicated that their success is close to the data cited above.

One of the concrete merits of the method being examined is the fact that the certainty of forecasts fluctuates quite insignificantly from decade to decade. This verifies the stability of the relationships in time and consequently the existence of possibilities for applying them in the compilation of forecasts during different stages of the circulation.

2. Regularities in the Transformation of the W, C, and E Forms and Distribution of Pressure and Temperature Anomalies in the Northern Hemisphere.

In recent years (1952 to 1957) G. Ya. Vangengeym considerably extended the prognostic relationships that were previously obtained, and plotted charts depicting possibilities and probable values of pressure anomalies, temperature anomalies and average pressure for almost all of the northern hemisphere for everyone of the five-month periods that followed a specific initial transformation of the macroprocesses.

The principal difference of this stage of investigations from the preceding one consists of the fact that the initial type of process in this case (W, C or E) is examined along with the consideration of its preceding history, that is, as a stage of more protracted transformations of the W, C and E forms.

We have already indicated on more than one occasion, in the first part of the book (See paragraph 1, Chapter III, and paragraph 1, Chapter V) that under actual circumstances, the W, C and E processes contain differences, the weather characteristics of which at various regions may differ from the typical charts cited in Chapter III. paragraph 1. The occurrence of these differences was explained by the fact that the process of the same form may be encountered in a series of different, longer transformations in the W, C, and E forms, i.e., may be recorded by us in the various stages of transformation.

It, therefore follows that consideration of the processes that precede the initial one permits a consideration of not only the form of the process that received and anomalous development but its variety as well, in the selection of the initial situation.

The initial process (W, C, and E) was determined in the following manner. The transformations of the W, C, and E forms were traced by means of the catalog, and periods of time when one of these forms (for instance W) remains stable for not less than 10 days, were selected. Then it was necessary that the form of circulation preceding the given process also be stable and remain in effect for not less than 10 days.

Investigations have revealed that if a process taking place in a given form remained in effect for over 10 days, it most frequently encompassed the major part of the month. Therefore, the initial processes and those preceding the initial process may be characterized with average monthly values of meteorological elements and of their deviations from the norm. [See note]. After analyzing the entire period from 1891 to 1956 G. Ya. Vangengeym evolved six basic types of initial transformations; W that evolved from E, W from C, E from W, E from C, C from W, and C from E. Each one of these initial transformations included six to twelve instances. In addition to that a series of groups were revealed where a combined form of circulation took place either during the initial month or during the month preceding the initial one

[Note:] It is necessary to utilize monthly averages as all the data pertaining to characterisitcs of the pressure and thermal fields for past years are based on months. The plotting of charts according to periods of similar circulation is a very difficult task and was not accomplished during that stage.

In all cases the macroprocesses (types W, C, and E) were examined in all of the initial situations (for instance, W from E) entering into a given group, which occurred in every one of the five successive months. It turned out that in all cases of a given group certain regularities in the changes among forms

W, C, and E are noted from month to month over a period of five successive months. This permitted a statistical processing of data for every group as well as the plotting of a graph showing the recurrence (transformation) of the W, C and E forms during a five month period after the initial condition.

After that, maps showing average monthly temperature anomalies, pressure anomalies and average pressure northern hemisphere for the corresponding months in all cases entering into a given group were matched. It turned out that the charts plotted for some of the months preceding the initial ones were analogous in their main features.

The value of the anomaly in the various squares for each month is determined on the basis of anomaly charts for every incident that entered into a given group. If the entire square or the major part of its area is occupied by a positive anomaly then the given square will have the sign "+". If a negative anomaly took place then the square contains "-". Then the number of plus and minus (+ and -) were computed individually in every square and the percentage expressing the total number of instances was calculated and entered in the middle of the square. Isograms were drawn according to data obtained through all these squares. As a result a chart showing the probability of positive (or negative) temperature anomalies) (or pressure anomalies) for a given month was evolved. Such charts were for the month preceding the initial one or for the initial month as well as for every one of the five months after the initial one for a given group (W from E).

The statistical processing of the recurrence of the W, C and E forms as well as the distribution of anomalies over the hemisphere for the remaining groups of initial conditions (W from C, C from W, C from E, E from C, E from W and others). Charts for transformations of W from E and W from C are contained in works by G. Ya. Vangengeym.

An examination of all the series of charts indicates the following:

1) The distribution of pressure and temperature anomalies over the hemisphere within an initial W circulation that originated from an E type, and with the W that originated from C, have concrete differences in a number of regions of the hemisphere. In connection with that the course of the further development of macroprocesses during a five-month period

after the initial month) as well as the changes from month to month in the weather conditions are also different. This indicates that in selecting an initial condition it is not enough to just establish the form of circulation. It is necessary to also consider the process that preceded it.

2) Considerable areas in the northern hemisphere are covered by the 100% probability lines and those close to it. This not only provides a basis for the utilization of the resulting charts in compiling forecasts for five months ahead but proves the presence of definite regularities in the development of W, C, and E forms over a period of five months after the initial month preceding the condition or state determined by the above method.

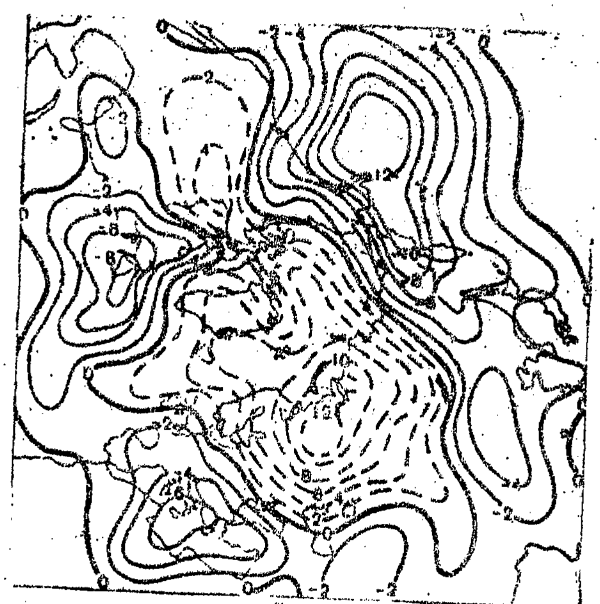
3) A distribution of pressure and temperature anomalies over the hemisphere for the next five months clearly indicates the process and stages involved in the further transformation of the initial form of circulation, regions where "violations" of the initial process first occur.

4) Years that form part of each group may be considered as homolog-years. Therefore if we, for instance, recorded a "fresh" transformation of W from E in an operational order that arose during a given season then the corresponding series of charts (group W, from E) may be used for the compilation of a background forecast for five months ahead. Having revealed which of the homolog years most closely resembles the current year, it is possible to utilize its charts for refining this background forecast in those regions of the hemisphere where the group charts show a probability value considerably below 100%.

New prognostic associations for the hemisphere have materially supplemented the former associations. If the winter (January, February) for example, is characterized by an anomalous development of the W form of process, then, according to former associations, the Spring will be marked by an anomalous development of processes of the E form. Such a forecast may be made more precise on the basis of the new associations. For that purpose it is necessary to determine which process (E or C) led to the occurrence in the past (i.e. in December) of the W form in January. After that a corresponding series of charts (W from E or W from C) are taken as well as graphs showing the transformation of W, C, and E forms for the following five months. Then they are matched

for the corresponding Spring months with data given in the table on the continuity of basic forms of atmospheric circulation from season to season cited earlier in this book. (Table 1).

The associations examined above have a probable character. Thereforethey may not always correctly indicate either the development of macroprocesses in the forthcoming months or the weather characteristicsfor especially those regions where the probability is considerably below 100%. In other words, it is possible that when in the initial season, for instance during the Winter, when processes involving the W forms are developed in an anomalous manner and by Spring they are replaced not by the E form, as it should be according to the regularities in the continuity (table 1 above), but by the C form. In this case the distribution of temperature anomalies for precipitation and other elements in the forthcoming Spring will not correspond to the type of distribution which should have taken place according to the charts cited above. It therefore follows that it is necessary to have additional criteria which would permit a consideration of this peculiarity in the transformation of the circulation during individual years that are different from the many year (normal) scheme of continuity; this is necessary in addition to the prognostic associations examined above. These additional criteria will be examined in detail later. Here we devote our attention only to the great significance of the probable associations cited above despite the fact that they do not always guarantee accurate weather forecasts. In addition to the possibility of using them in compiling a background seasonal forecast, their significance also consists of the fact that they indicate the most likely (normal) trend in the development of the macroprocess and the associated weather conditions for the subsequent season after their specific condition in the past season. The significance of these leading regularities permits the forecaster to make a proper evaluation of whether the transformation in the circulation in a given specific season is normal or abnormal. For instance, let us assume that in the initial winter season the W processes were developed and according to the supplementary criteria (see below) we obtained an indication of a possibility that by Spring, processes of the C form will develop. This indicates that in the given specific



G.

A chart showing changes in surface pressure with the transformation of W into E.

H.

A chart showing changes in surface pressure with the transformation of W into C.

year we are dealing with an unusual development of the macroprocesses. In such cases it is evidently necessary to conduct an especially thorough analysis of all data that would permit a forecast of the extreme instances.

3. Consideration of the Peculiarities in the Transformation of Forms of Atmospheric Circulation During Specific Years.

Above, we have pointed out that in utilizing the previously examined possibilities of prognostic associations there may be cases where the characteristics of the transformation of the seasonal circulation will differ from the normal scheme of continuity. In order to be able to compile a forecast of these cases and also to be able to have an opportunity to consider possible deviations from the normal scheme during specific years where the processes are developing in a normal direction the following supplementary methods are used:

a) The observation of characteristics involved in the exchange of air in the northern hemisphere as well as the consideration of the interaction among processes taking place in its various sectors.

b) A selection of homologs of circulation for the processes that are observed over a period of four to five months preceding the season covered by the forecast.

Let us now stop on a more detailed examination of each one of these additional criteria.

In matching charts showing the distribution of pressure anomalies that are observed under the W, C, and E forms (see illustration above) their main differences may be noted. The differences between charts showing the W and E forms are especially evident (see illustrations above) where the distribution of the anomalies is almost directly opposite: with the W form the lack of air masses and polar and pre-equitorial regions and the surplus of it in the tropical regions is evident. It therefore follows that in the transformation of the W form into an E form a specific exchange of air must take place in the hemisphere. Specifically a shifting of air into pre-polar and pre-equitorial latitudes and a movement of the air masses out of the subtropical regions.

In order to present the nature of air exchange that takes place in the hemisphere with the transformation of the W form into the E form in a clear manner the following method is used: pressure values derived from a typical chart showing the W form are

subtracted from the pressure values from a typical form E chart. The resulting pressure differences are plotted on a blank by assigning it a special sign and lines are drawn between similar differences (red color means negative, i.e., decreasing pressure, and blue color means positive values, i.e. an increase in the surface pressure). This type of chart is called a chart showing change in pressure observed in the transformation of the W form into the E form or briefly a chart showing the transformation of the W form into the E form. This chart is shown as chart G given below. Charts showing the transformation of W form into the C form (see chart H below) as well as charts for other types of transformation (C into E, C into W, E into C, and E into W) were also derived in a similar manner [See Note].

[Note:] Investigations have shown that in a region where there are rising pressure areas, areas of positive anomaly of pressure are formed and the opposite takes place in areas of decreasing pressure - a negative anomaly.

The comparison between charts depicting transformation of the W to the E form and the W into the C form indicates major differences among the air exchange characteristics in the hemisphere these two different types of transformation of the same form (see charts G and H given below). Therefore, it follows that, if during a certain period of time (for instance a month) processes of the W form are observed while the change in pressure from day to day will indicate an expansion of that form in the region of the Aleutian Islands and England, a drop over the European portion of the USSR and western America, in that case it means that the processes of the W form change in such a manner that they will in the future be replaced by the C form. If the pressure changes correspond to chart G given below showing the changes in the surface pressure with a transformation of the W into the E form. This will then mean that signs involving the evolution of a new form (E) is taking place in the background of the existing process which after a period of time will go back to the W form.

As already indicated in paragraph 1 of Chapter III the transformation of processes from one form into another does not occur at the same time over the entire hemisphere. Features of a new form may at first occur in one part of the hemisphere, then due to the interrelationships and interdependencies of the process

they may appear in the other regions of the hemisphere after after a period of time. For example in the transformation of the W form into the C form the high level ridge (block) may at first occur along the Aleutian Islands meridians and later in the Atlantic Ocean.

According to investigations conducted by Namias the transfer of disburbances from the Pacific to the Atlantic Ocean occur approximately on the fifth or seventh day.

Therefore by constantly watching the characteristics involved in the exchange of air taking place in the hemisphere and comparing it with the transformation charts, and also after studying the regularities and interactions of the processes within the hemisphere, it is possible to forecast the trend of the transformation of the initial form. That is, where the initial form W will become transformed into the C form or the E form, etc. A knowledge of this has an important bearing, not only for making the seasonal scheme showing the continuity of the W, C and E forms more detailed and precise, but also for a timely amendment of the forecast already in effect, if it proves to be incorrect. This question will be discussed in more detail below.

At this point we will examine how it is practically possible to observe the characteristics of the change of air in the hemisphere over prolonged periods of time. This problem could be solved by plotting daily isallobar charts. Such a method however is unsuitable for analyzing pressure changes over prolonged periods of time (several months). The annual course in the changes of pressure in this case could conceivably overlap the changes in pressure produced by a given macroprocess which would not permit the con- consideration of features inherent in the latter that are peculiar to the specific seasons.

In connection with that G. Ya. Vangengeym proposed a method for plotting integral curves of daily pressure anomalies. They were plotted in the following manner. Daily data pertaining to pressure were compared with the monthly norm for each individual station and deviations from the norm were determined which were then algebraically summarized. The values of these sums were plotted against ordinate axis and the days were plotted along the X axis. A curve was drawn along this data which is known as the integral curve. During periods when this curve was

rising the pressure at the station was above normal (positive deviations were forming), During periods when it was dropping the pressure was below normal.. If the pressure was equal to the normal level zero deviations were totalled and consequently the curve followed a course parallel to the X axis. The inclination of the curve towards the X-axis characterizes the intensity of the increasing or decreasing pressure.

/Note/ It is recommended to take a group of stations and to utilize pressure that represents an average for every day according to the data of this group.

Therefore the integral curve provides a visual representation of pressure changes in time at a given station in terms of its deviation from the monthly norm. Therefore the influence of the annual course is here excluded, and the course of the curves characterizes only the peculiarities of the macroprocess that is peculiar to the period of time that interests us at that time.

A natural question arises as to the number of the stations to be used in the compilation of integral curves so that the results yielded by such curves would correctly reflect the nature of air exchange in the hemisphere that occurs during the transformation of the W C E Forms. In order to answer this question let us once again refer to charts G and H given above. From them it is evident that during a transformation of the W into the E Form and the W into the C Form over large areas of the northern hemisphere, there are large regions having a similar change in pressure (increase or decrease). The extent of these changes is greatest at the center of the indicated regions and it is smallest along their peripheries. In plotting integral curves it is natural therefore to select points in the central portions of the areas under examination. Then the changes in pressure in those areas will characterize the entire region having similar changes and in its dimensions it will be maximal. In order to reflect the minimal changes also, it is possible to take points on the periphery of the indicated regions as well. The combined value of the curves for the selected points in this case will satisfactorally characterize the basic features inherent in the change of air within the hemisphere under circumstances where the W Form changes and the E Form and the W Form changes into the C Form.

In order to characterize other types of transformations additional points were selected from the central areas of the regions with increasing and decreasing pressure, that were peculiar to these transformations. It turned out that the predominant majority of these points were located in the same regions of the hemisphere which were already

selected as indicative for the transformations of the W into the E form and the W into the C form.

As indicated above (Paragraph I, Chapter III) typical pressure charts are plotted on the basis of a comparatively limited number of months during which an exceptionally strong development of the processes involving a given form took place. In order to verify the degree of representativeness of the selected points on the basis of material that encompasses all types of possible transformations the author conducted the following work. Charts showing anomalies of the average monthly pressure for all months from 1891 to 1955 were examined. A dot chart was plotted by entering the centers of all areas with positive and negative anomalies that were observed in every one of the indicated charts. Furthermore the number of dots in every ten degree square was counted and these figures were used to draw the Isograms. It turned out that the maximum number of centers was observed in those regions of the hemisphere which contained the dots that were selected earlier on the basis of transformation charts used in the plotting of integral curves.

This climatological processing of the material was used to prove the representiveness of the selected ten dots, /See Note/ which are seen in an illustration given in the first part of this book. This illustration also gives a schematic representation of the basic troughs and ridges peculiar to the W, C, and E Forms in the tropospheric layer. A comparison among them proves that the majority of the dots are situated under the indicated ridges and troughs. It is therefore understandable why the maximum changes of pressure and the predominance of the W, C, and E Forms are observed specifically in these regions of the hemisphere. They occur because it is in this area that, when the E Form transforms into the C Form, for example, a major reconstruction of the fields takes place throughout the tropospheric layer (and according to the available data in the lower stratosphere) which leads to a substitution of ridge with a trough or a trough with a ridge. Inasmuch as the surface pressure is the weight of the air column, the reconstruction of the high level fields must also be inevitably reflected in a change of surface pressure which is recorded by a corresponding course of the integral curves.

/Note/ More precisely, ten groups of dots.

Therefore, it is possible to see which regions of the hemisphere have a rising pressure and which regions have a decreasing pressure, on the basis of the integral curves.

By comparing the course of these curves with the transformation charts (see charts G and H that are above) it is possible to form an idea regarding the direction of the transformation involving the initial form and also to determine the regions of the hemisphere where the features of the new form initially occurred and to observe the movement of these disturbances into other regions of the hemisphere.

The selection of circulation homologs. In order to illustrate the manner of selecting homologs let us assume that it is necessary to select circulation homologs for a period from October to February of a certain year. For this purpose it is necessary: 1) to separate the continuously occurring macroprocesses into elementary synoptic processes(E S P). The name of each E S P is established, and classified according to one of the three forms of circulation W, C, or E by using typical cumulative kenomatic E S P charts that are cited in Vangengeym, G. Ya. Opyt Primeneniya Sinopticheskikh Metodov k Izucheniyu i Kharakteristike Klimata (Experience in the Application of Synoptic Methods in the Study of the Climate and of its Characteristics), State Publishing House for Hydrometeorological Literature, Leningrad, 1935.

2) It is also necessary to plot a graph of integral curves for the period from October to February of all ten dots (in different colors). A "linear representation" of the W, C, and E types are graphically represented along the axis of the abscissa of this graph where the days and months are entered. The periods occupied by the processes of the W Form are painted with a red color, the processes of the C Form are colored blue and the processes of the E Form are colored green.

3) It is necessary to compute the number of days in every month (October through February) - occupied by the W,C,E Forms and to compile a scheme showing their continuity from month to month. Let us assume that it turned out to be as follows:

October	November	December	January	February
W_{20} C_{11} into	E_{25} C_{5} into	C_{31} into	W_{21} C_{10} into	W_{28}

The numbers below the letters indicate the number of days during which the given form took place in the course of the given month.

4) By using a catalogue of the W C E types compiled for all days beginning with 1891 to find autumn-winter seasons during which a continuity of the W C E types was observed similar to the one that took place during the preceding period (October to February).

5) To define one of the following transformations: W from E, W from C, E from W, E from C, etc., in the interim between October to February and to refer to the corresponding series of charts for a given transformation which was discussed in detail under number 2 of this paragraph. Years that entered into the corresponding group will also be homologs both in the initial month and in the month preceding the initial one as well as in the following months.

6) To match the homologs selected under section 4 this paragraph according to the course of the integral curves during the period from October to February and according to the continuity of changes taking place in the E S P, noted in the linear representation of the W C E types. This is practically done by superimposing the graphs plotted on tracing paper for the preceding autumn-winter season over the analagous graphs of these seasons of the preceding years.

7) To match the year-homolog selected in sections 4 5 and 6 of this outline with a distribution of pressure and temperature anomalies in the hemisphere for every month from October to February which is comparable with the distribution of the anomalies in the initial autumn-winter season, October-February. Those that best match the initial one in the distribution of the indicated anomalies over the hemisphere are reserved for future analysis.

8) To carefully study the weather conditions (temperature and pressure anomalies, the predominating wind conditions etc.,) in all of the homologs selected in paragraph 7 of this section, for the region of the hemisphere for which the forecast is being compiled. In doing this special attention is directed in that the degree of similarity the weather conditions are observed from October to April in that region and that weather conditions that occurred here during the corresponding months of the year-homologs.

9) To analyze an epoch, 8 to 10 years, directly preceding the year which includes the season covered by the forecast. For that purpose the course of the integral curves, the diurnal pressure anomalies for ten dots and the course of the curves showing the recurrence of the W, C and E Forms and the Z, M_1 and M_2 types are traced on graph paper from the graphs of the many year course of the integral curves for the indicated 8 to 10 year period.

Table 4. Certainty of operational and climatological forecasts of temperature anomalies for 1947-1949.

Пределы погрешности (град.) (A)	Обеспеченность оперативных прогнозов (%) (B)	Обеспеченность климатологических прогнозов (%) (C)	Эффективность (%) (D)
	Март—май (E)		
±1	62	30	32
±2	84	54	31
	Июнь—сентябрь (F)		
±1	68	55	[illegible]
±2	90	79	12

Legend: a. Margin of error (degrees); b. Certainty of operational forecasts (%); c. Certainty of climatological forecasts (%); d. Effectiveness (%); e. March-May; f. June-September.

Table 5. Comparison of the certainty of operational and climatological forecasts for wind direction during March - October 1957-1949.

Допустимые погрешности прогноза (A)	Обеспеченность прогнозов (%) (B)		Эффективность метода (E)
	оперативных (C)	климатологических (D)	
Точное совпадение (F)	64	47	16
±1 румб (т. е. 45°)	80	58	23
±2 румба (G) (т. е. 90°)	87	69	18

Legend: a. Permissible forecast error; b. Forecast certainty (%); c. Operational; d. Climatological; e. Effectiveness of the method; f. Exact coincidence; g. Rhumb.

Matching the integral curves plotted on the tracing paper with the corresponding many year integral curves, epochs that are analagous to the initial epoch over a period of 8 to 10 years are found in previous years of the epoch or even just for five to six years. The year following such an epoch is considered a homolog for the year which includes a season to be covered by the forecast. It is usually possible to find three to four such homologs.

10) To once again review the homologs selected in paragraph 8 of this section and to establish whether they include a year or years selected in paragraph nine of this section as homologs for the year. If such homologs are found they are especially marked as they are analagous to the initial one not only in the processes of the autumn-winter season, but according to the circulation background of the year which contains these seasons, as well as according to the circulation background of the epoch which preceded this year.

11) In the homologs for the years selected in paragraph nine of this section, the types of processes and the weather conditions during months from October to February must be reviewed and matched with such processes for the initial autumn-winter season. The possibility is not excluded that some of them are analagous even in this period of time but were missed in the preliminary selection of the homologs (stages 3 to 8)

4. A Method of Compiling a Forecast for the Spring

Below we will schematically examine the basic stages for compiling a forecast for the circulation and weather conditions for the period from March to June using the regularities in the continuity of forms as well as additional criteria. These basic stages are as follows.

1) The form of the Macroprocess (Type W, C, or E) which developed in an anomalous manner in January and February is determined on the basis of the breakdown of processes for October and February that was accomplished. In our example these were processes of the westerly (W) Form.

2) On the basis of the table given above showing the continuity of basic forms of atmospheric circulation from season to season the form of circulation is determined which should occur in the spring. In our example after a winter with the W Form processes of the E Form will receive an anomalous development by spring (in April E plus W and in May "purely" E Form.)

3) The types of processes taking place in December are examined to determine the form that gave rise to the westerly circulation during January and February. In our example it originated from the C Form. Consequently, we consider the transformation group of W from C. Circulation of the W Form during January relates to the initial macroporcess and the December processes relate to the macroprocesses that preceded the initial one. Then the month following the initial one will be February, the second will be March, the third will be April, the fourth will be May and the fifth will be June.

In order to verify the fact that January corresponds to the initial month in the W from the C group and December to the month before the initial one the charts showing distribution of pressure and temperature anomalies over the hemisphere for these months are compared with group anomaly charts of these elements for the initial month and the month preceding the initial one of the selected goup (W from C).

4) Group graphs showing the change in the number of days with the W, C and E Forms (graphs showing the transformations occurring during a five month period after the initial month) are considered and a number of days with each one of these forms during February, March, April, May and June are determined. The forms of circulation that fall into April and May are compared with the forms of circulation that wer. earlier predicted (Paragraph 2 of this section) for these months, according to the circulation of January and February (according to the table given earlier showing the continuity of basic forms of circulation from season to season), while the forms occurring in February are compared with those actually observed during a given month of the current year.

In case of a divergence in the forecast of forms for these months, the problem is finally resolved on the basis of the consideration of circulation homologs (see below). The forecast of forms for February-June is compiled on the basis of group data of W from C and is then made more precise with the aid of the homologs.

5) The homologs for the processes of the autumn-winter season (October-February) are selected by a method which was explained in detail above.

6) The forms of circulation that were observed in every month from March to June are studied in the homologs selected in paragraph 5 of this section. At first all the homologs are compared with each other in both the general scheme of continuity of the W, C and E Forms from March to June and in the number of days with these processes for every month.

Let us suppose that all the homologs turned out to be concordant among themselves. Then they are compared with forms that were already forecast for these months in paragraphs 2 and 4 of this section. Let us assume that there are similarities in here as well. In that case, we'll make a deduction that this year the development of process from winter to spring will procede in a normal direction. Next, the number of days (individually for every form) which were observed for example in March of the homolog years and on the basis of the group graphs of the W from the C group is averaged out. This will then be the final forecast for the number of days with W, C, and E Forms for March.

An analagous method is used to compile the forecast of forms for the remaining months up to June.

However in matching comparable homologs with those obtained in paragraphs 2 to 4 of this section by a probable forecast, material divergencies may occur. In that case a conclusion is made that during a given year the processes from winter to spring will develop not in accordance with the many years scheme of continuity. We are then dealing with an extremum. Then the forecast of the W, C, and E Forms for every month is compiled as an average number of days from all of the selected homologs.

Here we give a preference to the homologs as they consider the peculiarities of transformations taking place in the given years (from October to February) which could have been evened out in the statistical processing of instances that entered into typical groups of former and new associations.

A third variant is also possible wherein homologs are not similar but are divided into two groups. One of them yields a continuity that is analagous to the one covering a many year period, and the other radically differs from it. In this exceptionally difficult case the first additional criteria is used, that of considering the interaction of processes and the nature of air exchange over the hemisphere (see above) during the month directly preceding the one covered by the forecast (in our case, February).

For that purpose the genesis of the W Form (for February) are carefully studied on the basis of integral curves of daily pressure anomalies as well as by the nature of the E. S.P. Let us suppose that the processes of the W Form during February are altered in such a manner that they must be replaced by processes of C Form in March. After that we study the forecast for March on the basis of both groups of homologs. While doing this in order to obtain a final forecast we dwell on that group which during March was characterized by an anomalous development of C Form.

the probabilities and probable values (paragraph 7 and 8 of this section). The comparison is first conducted on a hemispheric scale and then particularly thoroughly for the region for which the forecast is being compiled.

In a case where the homologs are similar both on a hemispheric scale and for the region covered by the forecastin the weather conditions but differ from the probability chart, the forecast is compiled by averaging the given homologs.

10) The forecast is usually realized in the form of a series of average monthly charts which include charts showing the average monthly temperature anamolies for the hemisphere (as a background) and on the basis of the region covered by the forecast in addition to charts of average monthly pressure and charts showing the dominant wind directions during every month (in quarter segments of the horizon).

5. The Certainty of the Method and Some Results Yielded by the Verification of Forecast Quality.

The results yielded by the verificati n of forecasts of temperature anomalies and the dominant winds compiled with the aid of this method for the period between 1947 to 1949 for the Soviet Arctic region is cited below. The verification was conducted on the basis of criteria examined in section 1 and 2 of chapter 6.

From table 4, it follows that the effectiveness of the method (i.e., the difference between methodological and climatological forecasts) amounts to over 30% during spring months and to approximately 12% in the summer and autumn months. The certainty of operational (methodological) forecasts of temperature anomalies fluctuates between 62.0 and 67.8% with a permissable margin of error of plus or minus one degree and from 84.4 to 90.2 degrees with a permissable margin of error of plus or minus two degrees.

From the table, table 5 shown above, it follows the certainty of methodological forecasts for wind as well as for temperature exceeds the certainty of climatological forecasts and the effectiveness of the method amounts from 16 to 22%. The certainty of methodological forecasts with a permissable margin of error of plus or minus two rhumbs (quarter segment of the horizon) amounts to 87%.

The verification of forecasts for temperature anomalies compiled on the basis of this method for 1949-1955 (April - October) was accomplished according to formula cited in section three of chapter six.

Later, in March, we continue to watch the characteristics of the development of the macroprocesses in the hemisphere. If we will then note that the March C Form is changing in such a manner that a type of processes which were forecast on a basis of a given group of homologs occurs by April then the forecast remains in effect. In a contrary situation the forecast for the subsequent month may be altered by using another group of homologs if a study in the changes taking place in the March processes provides a basis for the supposition that homologs of the second group will be "active" in April.

It therefore follows that a great advantage of the method being examined over other methods is the fact that this method offers a possibility for compiling forecasts well in advance and also provides a possibility to make them more precise on the eve of the following month.

A positive factor is also that this method permits utilization of not only the best homologs but the entire group of homologs by shifting to another group of them in time if this is required by an analysis of the accuracy of the forecast during the current month.

This basically completes the compilation of a forecast of the development of macroprocesses (of the W,C and E Forms) for the period of time covered by such a forecast. The next problem is the compilation of a forecast for weather characteristics which should occur from March to June in connection with the W,C and E Forms that were forecast the successive nature of the changes occurring among them.

7) By using a series of charts showing the probability and the probable values (see charts A -- F given earlier in the book) the distribution of the temperature and the precipitation anomalies over the European territory of the USSR as well as the anomalies of the thawing of rivers are predicted.

8) Using the group charts of the average monthly temperature anomalies as well as pressure and mean pressure anomalies for the hemisphere involving the W from the C group, the distribution of them over the hemisphere from March, April, May, and June are forecast. The prognostic charts for April and May are compared for the European territory of the USSR with the forecast compiled under paragraph 7 of this section.

9) The weather conditions in the hemisphere within the group of homologs that was adopted earlier (paragraph six of this section) is studied for forecasting the macroprocess. Then the weather conditions within the homologs are compared for every month with a forecast for these same months compiled on the basis of charts showing

For the period from April to June good forecasts comprised 43% of the total number of forecasts satisfactory forecasts 38%, poor forecasts, 19%. The number of forecasts for the period from October to July is somewhat lower than from the period from April to June. This, as evident from the table above, occurred for the period from 1947 to 1949 as well. On the whole for the entire period (April to October) 35% of the forecasts were good, 41% were satisfactory and 26% were poor.

6. Prospectives for the Further Development of the Method.

It follows from the above that the examined method is based on a study of the irregularities in the development of the general circulation of the atmosphere, on a consideration of the local synoptic peculiarities of the region covered by the forecasts and of its meteorological regime, as well as on a thorough analysis and consideration of the characteristics of the preceding macroprocesses. This from our point of view is the principal argument in favor of considering the given method as prospective. This conclusion is also substantiated by the results obtained in the practical application of this method which was already discussed in detail above.

The present state of the method must be considered only as a first stage in its development. There are still a considerable number of questions and problems that must be resolved. The principle ones are as follows:

1) A more detailed breakdown of the forecasts according to periods of similar circulation. At the present time, the forecasts are issued in the form of mean monthly characteristics of thermal, pressure and wind fields. A detailed breakdown of the elements is accomplished only on the basis of ten day periods and even then without adequate methodical elaboration. Therefore, the most important task is the establishment of regularities in the development of the W, C, and E Forms that permit a detailed breakdown of the forecasts for four to five months according to periods of similar circulation.

2) Consideration of the intensity of atmospheric circulation. Basic errors in the forecasts of temperature anomalies relate to the degree of the anomalies with a relatively successful forecasting of their value. This is a consequence of the fact that with a correct forecast of the general (background) characteristics of the macroprocesses the intensity of the processes are not always taken into full consideration.

III Method of Long-Range Forecasts for Short Periods in Advance.

Long-range forecasts of the weather for short periods in advance with the aid of the macracirculation method were first used beginning in 1946. This method was primarily based on the utilization of homologs.

In the following years M. Kh. Baydal, N. A. Aniskana, L. A. Dydina and others completed a number of investigations in studying the irregularities of the continuity of the E S P and the types of weather associated with them. The results of this investigations were partially generalized in Dydina, L. A., O Printsipakh Sostavleniya Dolgosrochnykh Prognozov Pogody Maloy Zablagovremennosti Dlya Arktiki (On the Principals of Compiling Extended Weather Forecasts for the Arctic Region), "Water Transport" Publishing House, 1958. It must also be noted that the most concrete and tangible results of the investigations relate to the method of forecasting for the first E. S. P., i.e. the nearest three to four days. As far as the forecast for the second and third E. S. P. are concerned, up to the present time their compilation is based on the utilization of homologs.

Forecasts for a period of from 8 to 10 days provide a chart showing the average distribution of pressure for every E.S.P., the basic trajectories of cyclones and anticyclones, the dominant wind directions (in quarter sections of the horizon), the degree of wind deviation from the dominant directions, the course of the wind during the 8 to 10 day period covered by the forecast (the wind data is given at the beginning, the middle and at the end of the period), the wind velocity, course of the wind by days during the first three days, the predominant and extre... air temperature values.

Forecasts covered in an 8 to 10 day period are regularly made more precise both by compiling three day forecasts and by means of an overlap of the irregular forecasts of the last few days of the preceding forecast period. Let us now examine the regularities that form a basis for the method and we shall demonstrate how forecasts are compiled on their basis.

1. A Study of the Regularities in the Continuity of the E.S.P. and the Weather Conditions Associated with them.

At the beginning of this chapter it was pointed out that the irregularities inherent in the continuity of the E.S.P. which must form a basis for the forecasts for short periods in advance must be studied on the background of more extensive transformations of the W, C and E Forms; the E.S.P. are the elementary stages of those forms. Let us know ellucidate this principal in somewhat greater detail. For this purpose let us select several Januaries from the

catalogue where the entire month was dominated by the same macroprocesses, for instance of the W Form. By comparing the E.S.P. with the nature of their successiveness all of which occur during this month we shall easily prove that they not infrequently are quite different. A natural question arises - how can it be explained that the processes of the same form occurring in the same month can consist of different elementary stages (E.S.P.).

An investigation of this problem has indicated that the nature of the E.S.P. and their successiveness depend on which of the chains of the more prolonged dominant features gave rise to the given form. For instance in an example examined in Girs, A.A., Meteorol i Gidrol. (Meteorology and Hydrology), No. e, 1956, processes of the W Form during January of 1932 arose from processes of the E Form in November and the W plus C Forms in December. Subsequently, they transform into the C Form. Processes of the W Form in January of 1916 arose from the W plus C Forms in November and the W plus E Forms in December, and transformed into E Form. A scheme of these transformations is as follows:

	November		December		January		February		March
1931/32	E_{25}	$\longrightarrow$	$W_{14} + C_{11}$	$\longrightarrow$	W^{1}_{26}	$\longrightarrow$	C_{26}	$\longrightarrow$	$C_{14} + W_{10}$
1915/16	$W_{16} + C_{10}$	$\longrightarrow$	$W_{16} + E_{8}$	$\longrightarrow$	W^{11}_{81}	$\longrightarrow$	$W_{17} + E_{12}$	$\longrightarrow$	$E_{21} + W_{10}$

Therefore the W^{1} and W^{11} in the indicated Januaries being analogous macroprocesses in their outstanding circulation features (according to their former circulation) are at the same time stages of various longer transformations of the W, C and E Forms. Therefore the E.S.P. from which they consist, are different which is easily seen from the catalogue or by the daily synoptic charts. This difference in the selection of the E.S.P. which form the processes of the indicated Januaries explains why the processes W^{1} W^{11} relate to different varieties of the W Form (see paragraph four, section 1, of chapter three).

Such structural differences between two analogous macroprocesses are quite natural and are easy to explain in physical terms. They must inevitably arise since processes of the W Form in both of these months bear features of both the processes that preceded them and the features of processes that follow them. Both of which are different in each case. Therefore it follows that in studying the irregularities of changes in the E.S.P. within a given month (January) we cannot isolate it from the more prolonged transformations which in the end determine both the "composition" of the E.S.P. in a given month and the successiveness of their changes.

Therefore in selecting homologs for "small scale" processes we cannot limit ourselves to a comparison of processes and weather characteristics for just that short period of time. It is necessary to select at first the analogous processes on a basis of the general background, i.e. on the basis of more prolonged transformations of the W C and E Forms and only then to find analagous processes for shorter periods of time (eight to ten days) from among them.

Proceeding from this basic principal, L. A. Dydina studied the peculiarities of the pressure fields and the weather conditions associated with them in the arctic region. On the basis of material covering a prolonged number of years (from 1939 to 1953) L. A. Dydina conducted a typification of the baric field according to the E S P. The latter are classified into 16 basic and nine supplementary types, which are then classified into six typical groups (a,b,c,d,e,f). The dominant winds at a number of stations located in the region covered by the forecast and its course from day to day is shown for each one of these groups.

Furthermore, typical groups of the E S P that were established were taken as the initial condition and studied as a probability that a given process will reoccur in the E S P as well as a probability that it will be replaced by every one of the other typical situations. As a result statistical characteristics depicting the continuity of the E S P were obtained, and which are utilized for forecasting the type of processes for the next E S P.

Further investigations permitted L. A. Dydina to reveal which typical situation is most likely to occur under the various forms of atmospheric circulations (W, C or E) and to relate these typical situations with the characteristics of more prolonged transformations of the E S P and W, C and E Forms.

2. Additional Criteria Utilized in Compiling Forecasts for the First Three Days of the Forecast Period.

In addition to the regularities inherent in the continuity of the E S P and their association with transformations of the W C and E Forms a number of other dependencies obtained by various authors are also used in compiling forecasts for the first three to four days. With the aid of these additional criterias it is possible to compile a scheme showing the development of synoptic processes for the first E S P (three to four days) which may then be compared with the forecast scheme for these same days, that was obtained on the basis of other data (homologs, E S P continuities on the basis of typical groups).

The additional criteria include the following dependencies:

(a) Distribution of the source as of heat and cold within a troposphere in the initial E S P and their relationship with a distribution of basic pressure fields within the next E S P;

(b) Advection of air masses in the troposphere and changes of the surface pressure in the initial E S P and their association with the nature of the high level pressure field of the next E S P;

(c) Advection of air flows in the troposphere of the initial E S P and their relationship with changes in the ground level pressure during the subsequent E S P;

(d) The mutual position of the horizontal pressure and temperature gradients in the initial E S P and their relationship to the changes in surface pressure during the subsequent E S P;

(e) The relationship between pressure changes in the troposphere and those close to the surface of the earth.

Let us briefly examine each one of the indicated associations.

Distribution of the sources of heat and cold in the troposphere during the initial E S P and their association with the distribution of basic pressure fields in the next E S P. K. I. Kashin and M. V. Gritsenko investigated the interdependence between the day to day shift of the ground level pressure system centers with the distribution of heat and cold source regions in the troposphere. They thereby established that cyclones usually shift in the direction of and under outcrops of heat in the troposphere while the anti-cyclones shift in the direction of and under outcrops of cold.

L. A. Dydina indicated that this interdependence may be expanded over a period of time longer than 24 hours, specifically to include an E S P. For this purpose she compiled cumulative maps showing the sources (outcrops) of heat and cold for each E S P for 1948 to 1955. Furthermore a demarcation line was plotted on these maps that was derived from the surface cumulative map of the subsequent E S P. It turned out that this line coincides well with the position of the demarcation line that was drawn between the sources of heat and cold for the initial E S P.

As a result of the calculations that were conducted it was found that from 70 to 90 % of all sources of heat and cold at 500 and 700 mb of the initial E S P correspondingly coincide with ground level cyclonic and anti-cyclonic areas of the next E S P.

The application of this dependence in practical work of compiling forecasts for the E S P yielded positive results. The planimetery of the prognostic and factual pressure fields which had coincident symbols indicated that

absolute coincidence among them amounted to 65%.

Advective exchange of air masses in the troposphere and the changes of surface pressure in the initial E S P and their relationships with the characteristics of the upper pressure field of the next E S P. N. A. Aniskina determined that those parts of the upper Pressure field of the initial E S P where an advective exchange of heat is observed in the troposphere with an increasing pressure on the ground surface the subsequent E S P includes the formation of an upper trough or a intensification of a trough that already existed there. The certainty of this interdependence amounts to 70%. If the increase (decrease) of pressure at ground level however, during the initial E S P corresponds to an advective exchange of cold (hot) air at the upper level then by the next E S P the upper 500 mb field will change in 63% of the cases within plus or minus five decameters and in 37% of the cases it will change more than plus or minus 5 decameters.

Such a dependence is explained by the fact that in a case where there is an advdctive exchange of heat in a dynamic increase at ground level pressure, both these factors are conducive to an increase in pressure aloft, i.e., to a intensification (or the occurrance of a new) ridge in the next E S P.

In an analogous manner when there is advective exchange in the troposphere and a dynamic drop of ground level pressure conditions that are conducive to the deepening of the existing trough or the occurrance of a new one in the next E S P are created.

Advective exchange in the troposphere of the initial E S P and their relationship with the changes in surface pressure during the subsequent E S P. N. A. Aniskina and L. A. Dydina in analysing the data for 1939 to 1950 (for June to October) for the Atlantic-Eurasian sector, determined the following rule: if the initial E S P includes a simultaneous combination of the advective exchange of heat (advective exchange of cold) at the 500 to 1000 mb level and a divergence (convergence) of isohypses at a level of 700 mb then the following E S P will include a decrease (increase) of surface pressure in this region in 92% of the cases.

Individual studies of the advective factors indicated the following:

(1) In 67% of the cases after an advective exchange of heat (cold) during the initial E S P, a decrease (increase) in surface pressure in that region is observed during the next E S P. In 24% of the cases such a relationship is not observed and in 9% of the cases in the next E S P does not change;

(2) In 80% of the cases after a convergence (divergence) of the isohypse during the initial E S P a decrease (increase) of surface pressure in a given region is observed during the following E S P. In 15% of the cases such a corresponding reaction is not observed and in 6% of the cases the pressure remains unchanged.

Relative position of horizontal pressure and temperature gradients in the initial E S P and their relationship with changes of surface pressure during the next E S P. N. A. Aniskina and L. A. Dydina investigated the relationship between the position of temperature gradient obtained from a 500 to 1000 mb chart, of the pressure gradient on the surface during the initial E S P on the basis of material from 1939 to 1950 with changes in surface pressure during the next E S P. It appeared that in 85% of the cases when the initial E S P contained a temperature gradient which deviated to the right (left) of the pressure gradient a decrease (increase) in surface pressure was observed in these regions in the next E S P

The relationships between pressure changes in the troposphere and by the surface of the earth. B. P. Malykh indicated that during the period of the development of pressure formations the magnitude of the change in the absolute gerapotential of the pressure surfaces increases from the bottom up. The changes attain a maximum at a level of 300mb. In cases where the pressure formations are destroyed the magnitude of the change in the absolute gerapotential decreases with altitude. The minimum changes in this case are recorded at a level of 200 mbs.

Statistical investigation was conducted of the problem of determining to what degree the intensification or weakening of pressure formations that are characterized by the relationships between change and altitude between the gerapotential as indicated above may be considered as a tendency of the future development of these formations in the next E S P. For that purpose cases of deepening cyclones and intensifying anticyclones where the changes in pressure are close to the surface of the earth where less than those at altitudes of 500 mbs (cumulative changes were examined). Then the evolution of these pressure formations in the next E S P were studied. Decaying cyclones and weakening anticyclones which had a total sum of pressure changes close to the ground greater than the sums of changes in the gerapotential at an altitude of 500 mb during the initial E S P [illegible].

It turned out that in 75% of all cases (out of 31cases) of cyclones and 84% of all cases (out of 31) anti-cyclones changes in pressure formations that began to take shape in the first E S P where preserved in the next E S P as well.

Therefore this rule may be used in forecasting the evolution of clearly expressed pressure formations for the next E S P period.

3. Method for Selecting Homologs.

As already indicated above, in compiling forecasts for a period of ten to eight days on the basis of a macrocirculation method the circulation homologs are also used. Therefore let us examine in somewhat greater detail the method of selecting homologs for an extended forecast.

Let us assume that we must compile a forecast for a period of from 1 to 10 August of some year. In that case the initial processes for the forecast will be those observed in the third to ten day period of July. Selection of homologs for these processes may be represented as follows:

(1) A breakdown of the processes into E S P for June and July is made on the basis of diurnal charts of the hemisphere in every one of the E S P are classified as a certain form of circulation (W, C or E). Let us assume that during July processes of the C Form were observed for 31 days (C31).

(2) A ten point integral curve graph is plotted for Juneand July in which the E S P and the W, C E types are shown along the x-axis.

(3) The form of circulation which was forecast for August in the long range forecast is taken into consideration. Let us assume that an anomalous development of processes of the E Form were forecast for August. In that case the processes of the first ten days of August covered by the forecast must develop on the background of the following more protracted transformations of the W, C E Forms:

June ------------ July ------------ August
W ------------→ C ------------→ E

(4) The catalogue is used to find instances that occurred in past years where an analogous sequence of circulation forms and an analogous course of curves during June and July were observed.

(5) The E S P for the third ten day period of July is carefully analysed for the nature of the macroprocess in the hemisphere and in the forecast region. At the same time

it is determined which type of pressure field (according to L. A. Dydina) may be related to the last E S P that occurred before the forecast.

Utilizing the regularities and the continuity of the E S P established in the book entitled "On the Principal of Compiling Extended Weather Forecasts for the Arctic Region", "Water Transport Publishing House 1958". It is decided which type of process in a given region is the most probable during the first E S P of the forecast period which was previously projected on the basis of data regarding the continuity of the E S P (according to L. A. Dydina).

(6) Peruses during the third ten day period in July for all homologs are analysed and those homologs are found which during that ten day period have been observed to contain E S P which closely resembles those in the initial ten day period both in their characteristics and their successiveness in the hemisphere and in the forecast region as well.

(7) Those homologs selected under paragraph six of this section which in the first E S P of the forecast period had a type of macroprocesses in the hemisphere and in the forecast region which is analogous to the one outlined for this E S P on a basis of a scheme of continuity and additional criterias, (see paragraph five of this section). The homologs selected in this manner are utilized for the compilation of a forecast for the nature of weather processes both for the first three to four days and for the eight to ten day period.

4. Scheme for the Compilation of Forecasts for a Three to Four Day Period and an Eight to Ten Day Period.

Compilation of a forecast for the nature of synoptic processes and weather for an eight to ten day period in a day by day detailed forecast for the first three days may be described in terms of the following basic stages:

(1) The processes occurring during the month which contains the initial ten day period and those contained in the preceeding month are analysed. The form of circulation and the successiveness of the E S P are established at that time. The form of circulation during the month containing the ten day period covered by the forecast is derived from the extended forecast.

(2) The type of process during the first E S P of the period covered by the forecast is determined on the basis of schemes showing the continuity of the E S P and also on the basis of additional criteria.

(3) The homologs are selected.

(4) The group of homologs selected under step 3 above the weather conditions in the region covered by the

forecast are analysed on the basis of data from representative weather stations. At that time the predominant wind directions are established as well as the most likely wind deviations in every section of the region are determined [see Note] as well as the wind velocities and possible wind velocity limits.

[Note] Sections of the region are determined on the basis of a similarity in the process and in the weather. They alternate from forecast to forecast.

For this purpose it is convenient to use complex graphs [See Note] showing the course of meteorological elements from period to period which must be compiled for every weather station in the region for all months of the available number of years. Examining such graphs (they are usually compiled on especially lined paper) for all homologs for a given month it is usually easy to reveal typical features in the course of the meteorological developments during the eight to ten day period for the entire group.

[Note] The complex graph shows the course of the temperature and pressure diurnally in the form of curves as well as in the weather characteristics with the aid of common synoptic symbols.

As a result of this analysis a weather forecast for the individual sections of the regions included in the forecast is compiled.

(5) The course of the wind from day to day during the first three to four days of the forecast period is analysed in detail. For that purpose in addition to a study of the homologs statistical data regarding the recurrence of different directions and velocities of the wind at stations located within the region covered by the forecast under every type of processes which are contained in a work by L. A. Dydina are utilized. As a result a detailed forecast for the wind for the first three days covered by the forecast is compiled.

(6) On the basis of data yielded by the group of homologs charts showing distribution of pressure in every E S P forecast period are compiled. If the neighboring E S P are analogous in the distribution of the pressure field a single prognostic chart may be compiled for them.

(7) Cumulative kinematic charts of all homologs contained in ten day periods that correspond to the ten day period covered by the forecast are analysed. At the same time, the most likely courses for the movements of cyclones and anticyclones in the region on the basis of which the forecast is being compiled are determined. They are marked as arrows on the corresponding prognostic charts of average pressure.

(8) Forecast of wind is shown in a visual form in the following manner. Small circles are drawn on the geographical base that include a certain area of the region covered by the forecast. Within that circle there are two or three additional smaller circles. Part of the predominant winds are differentiated in the form of a sector and colored with a red color. A portion where wind deviations are expected are colored green. The forecast of the beginning of the period (two to three days) is expressed in the circle closest to the center, the one for the middle of the period - in the central circle, and the one for the end of the period - in the outside circle. The prognostic gradations of wind velocity the limits of its intensification and also the predominant and the extreme temperature values are entered by every sector on this chart. During the period of the forecast the actual wind directions for every region (socle) is entered on these colored sectors with dots. The data is derived from the meteorological dispatches for four forecasts. The dots are placed in that radius which represents the wind direction that corresponded to the one observed during the given period. These charts are then used to compute the number of dots that appear in the forecast sectors and the percentage of correct forecasts are then determined.

5. Certain Data on the Effectiveness of the Method and the Correctness of Extended Forecasts.

The verification of extended forecasts for a period from 1954 to 1956 indicated that forecasts of the pressure field for periods of eight to ten days were correct in 73% of the cases. The average correctness of the forecasts for the wind direction for the period from 1953 to 1956 amounted to 66%. The certainty of climatological forecasts on the predominant wind directions on a quarterly basis (for ten day periods) amounted to 59%. Consequently, the effectiveness of the method as applied to the given element amounts to 7%. This same method for forecasting temperature of the air has a somewhat higher effectiveness (12 to 15%).

6. Prospectives for Further Development of the Method.

Development of the extended forecast method is in many ways associated with our knowledge of the forms of atmospheric circulation as processes taking place within the hemisphere and regularities inherent in their transformation. Therefore, the basic task is a multi-lateral study of the regularities involved in the continuity pattern of the E S P as the elementary stages of the more extensive processes (W C and E Forms).

An important task also is the proper consideration of the intensity of the processes and primarily the intensity of the pressure and thermal fields with which the degree of cyclonic activities is closely associated.

Of considerable importance is also the consideration of local synoptic and orographic peculiarities of the region which is covered by the forecast.

CHAPTER XII

A SURVEY OF METHODS AND INVESTIGATIONS IN THE PROBLEM OF LONG-RANGE FORECASTING IN THE VARIOUS COUNTRIES OF THE WORLD

In the preceding chapters of the second part of the book, methods for long range weather forecasting presently used in the USSR and the USA by the official weather service agencies of these countries, were examined. The indicated methods represent more or less formulated viewpoints that proceed from certain principals and have certain operational methods that permit irregular compilation of weather forecasts for various periods of time. These methods also have certain advantages over the utilization of climatological norms as forecast values which provides a basis to use them in practice. They are all to a degree based on the regularities of the general circulation of the atmosphere. As a rule in the analysis and forecast compilation by these methods synoptic and upper level charts of the northern hemisphere are used.

In addition to the indicated more or less formulated methodological systems a number of countries utilize various types of prognostic relationships that with a certain degree of success permit the forecasting of weather or of its various individual elements. These methodological systems as a rule contain certain individual methods that were examined in the introduction to the second part of this book. They may not be called formulated methodological systems even though in a number of cases they may permit the compilation of forecasts that to a certain degree satisfy the interests of certain sections of the economy or specific end users. Other countries have not even developed these types of prognostic relationships and at the present time are conducting only certain investigations in that direction.

In this chapter we will devote our attention to a brief survey of such methods and approaches assuming that this will provide the reader with the possibility of gaining a better understanding of the contemporary state of the problem under examination on the world scale.

I. Federal Republic of Germany

As already pointed out in the introduction in Germany beginning with 1929 investigations were conducted for the purpose of evolving methods for long-range weather forecasting under the direction of Baur. A special institute was established for that purpose.

Beginning with 1932, the institute of long-range weather forecasting issued forecasts for 10 day periods in July and August and beginning with 1937 they issued forecasts covering the period from June to September. Forecasts covering a month and a season were also issued. Methodological basis for these forecasts are described in a monograph entitled Baur, F., Meteorologische Zeitschrift, 54,437-444,1937 as well as in an article by Baur in the Compendium for Meteorology for 1951. Below we will briefly stop on the examination of the principal basis of the indicated methods and we will also examine how forecasts are compiled with their aid.

In the first stages of the investigations Baur attempted to solve the problem of forecasting by a purely statistical method. For that purpose he searched for various types of associations of changes in the meteorological elements in one region and the changes in meteorological elements in other regions of the northern hemisphere during the preceding period of time. The resulting relationships were used as a basis for formulating seasonal and monthly forecasts. In addition to that, a large number of corelation co-efficients were found that indicated a association between a subsequent change in pressure at some meteorological station and the value of a number of elements which have a direct bearing on the pressure during the preceding 10 day period. In that manner multiple correlation tables were compiled with the aid of a chart which was drawn showing the probable distribution of surface pressure for the next 10-day period. With the aid of analogues selected for the preceding 10 day period the indicated probable forecast was made somewhat more precise.

The utilization of such methodological approaches did not, however, lead to effective prognostic results especially with regard to seasonal and monthly forecasts. In connection with this the subsequent methodology of 10-day forecasts was perfected by using iro-synoptic investigations and first of all by an understanding of the macrosynoptic situation, (Crosswetterlage) which was already mentioned in section 2, chapter 4 in the examination of Baur's typification.

In studying the macrosynoptic situation and factors that determine its changes Baur came to the conclusion that of the great number of terrestrial and cosmic factors, volcanic eruptions, polar seas, ocean currents, the influence of the moon, the motion of the pole and solar activity. Solar activity alone has material significance that is associated with changes in the ultra-violet and corpuscular solar radiation. According to Baur "fluctuations in solar radiation represent sets of conditions that direct the course of the weather on a large scale. Therefore, one of

the main premises for success in long-range forecasting is an intensive development of solar physics".

In addition to that considering that in order to arrive at a solution of the problem of long-range weather forecasts the combination of synoptic and statistical methods are of great importance, Baur conducted a typification of macroprocesses and established 17 types of macro conditions for the European region. The further task is the determination of seasonal recurrence of these types and their continuity for the consideration of mutual influences of the circulations taking place in neighboring regions. Baur also considers that a clear resolution of these problems has a incomparably greater significance for long-range forecasting especially for mean forecasts than the numerous harmonic and rhythmic analysis undertaken in many institutes."

For the purpose of compiling forecasts for five day periods Baur utilized multiple correlation tables and the results were conducted by Scherhag on the dependence between the distribution of surface pressure and the movement of three and 24 hour isallobaric sources, the characteristics of upper currents and their convergance peculiarities at surfaces of 500 and 225 mb.

Let us examine these two methods in somewhat greater detail. In order to compile multiple correlation tables which could be used for forecasting pressure changes Baur proceeds from the expression for

$$\frac{\partial p}{\partial t} = \frac{p}{RT}\left[\frac{k}{1-k}\frac{dq}{dt} + \left(gv - \frac{kT}{1-k}\frac{\partial v}{\partial z}\right) + v\left(\frac{dv}{dt} + c\,v\right) - \frac{p}{1-k}\,div_2\,\bar{v}\right]$$

Here $div_2\ \bar{v}$-is the horizontal velocity divergence $k = \frac{R}{cp} = 0.2884$ $\frac{dg}{dt}$ - amount of heat obtained by a unit of mass of the particle in motion for a unit of time, c- is the constant.

On the basis of his work in Meteorologische Zeitschrift, 54,437-444, 1937 the right portion of the equations are replaced with values which may be interpreted statistically. As a result, the following variables are obtained, which influence the future change in pressure and which are used as introductory data for the multiple correlation table: x_1- pressure at sea level at mb at 14 hours during the day of the forecast at a given station, x_2- change in temperature (in centigrade) from 14 hours of the preceding day to 24 hours of the day when the fore-

cast is being compiled x_3 - change of pressure in mb for the same 24 hours, x_4 - the degree of cloudness of a day when the forecast is being compiled, x_5 - change of pressure in mb for seven hours on the day of the forecast.

After compiling such tables for all meteorological stations in the region that interests us for an available number of years it is possible to use them in determining the mathematical probability of pressure changes for the nearest two to three days.

In compiling forecasts in that manner distribution of surface pressure for a period of 24 hours in advance, it is possible to use it in computing the volume of the relative geopotential 500/1000 mb and to determine the change of this value from the initial day to the first day of the forecast. By adding this difference to the value of the surface pressure forecast 24 hours in advance we obtain forecast of the altitude of the 500 mb surface. On the basis of the latest data, a 500 mb prognostic chart for the next 24 hours is drawn.

By using this chart in accordance with the work by Scherhag, R., Forsch. Efahr. Ber. Reider Wetterd Reiche, Bd. II, 1943 a prognostic chart showing the distribution of surface pressure for the second day is compiled. It is made more precise with the aid of multiple correllation tables. With the aid of that chart and using the same method it is possible to obtain a 500 mb prognostic chart for the second day and by using the latter chart to compile a chart of surface pressure for the third day which is also made more precise by means of multiple correlation tables. A 96 mb chart is used for that purpose. Forecasts of the surface pressure field for the fourth and fifth day were compiled both by means of the method indicated above and by the utilization of a number of other supplementary methods of a synoptic and statistical nature (types of interactions, their recurrence and continuity, analogues, multiple correllation tables and others).

These are the principal basis and technical methods which form the foundation for the compilation of forecasts for five days according to Baur's method.

Let us now briefly stop on the methodology of compiling 10 day forecasts. The five day forecast compiled on the basis of the method examined above is used as a foundation for the compilation of these ten day forecasts. For forming a forecast for the second five day period of the ten day period covered by the forecast, multiple correlation tables are used (compiled especially for ten day forecasts) in addition to analogues. The analogues are selected at the beginning of the ten day period preceding

the ten day period covered by the forecast, in view of the fact, as justifiably pointed out by Baur "that the preceding development, which led to a certain macrosynoptic situation, must be considered to a much greater degree than in cases where the diurnal synoptic charts are examined ". In selecting analogues a similarity in the circulation of the regions of North America, Europe, Asia and the Polar Circle is required.

Baur compiles forecasts for a period of a month and a season, according to Walker, on a purely statistical basis. In doing that he also utilizes analogues. The correlation equation includes a considerable number of dependencies among the changes of elements in the various regions of the northern hemisphere. For example, for predicting the average temperature in March for Central Europe the following equation is available:

$$E(y) = -0.01X_1 -0.08X_2 \quad 0.09X_3 + 0.19X_4 + 0.10X_5$$

Here E(y) is the mathematical anticipation of temperature anomalies during March (average for three stations -- Berlin, Vienna and De bilt), X_1 -- is the mean pressure for February at two stations: Stikkisholm, Haparanda; X_2 -- is the mean pressure anomaly for February at Sverdlovsk; X_3 -- is the mean pressure anomaly for February at three stations: Milan, Rome and Malta; X_4 -- is the anomaly of temperature differences during February-October in Central Europe; X_5 -- is the anomaly of mean pressure at Rome during December and January.

According to Baur, long range forecasts should be issued for practice and widespread utilization only in those cases where the benefit derived from successful forecasts will be immesurably greater than the harm that results from incorrect forecasts. Such a situation, according to Baur, is possible only when forecasting with the aid of the regression equation, the corelation coefficient will be no less than 0.80, the correctness of the forecasts of anomalies must not have a value of below 0.75, and forecasts of indirect elements must not be below 0.92. Inasmuch as such high requirements are at the present time unattainable, according to Baur -- "it is necessary to deflect all the requirements for a regular issue of monthly or seasonal forecasts under the present state of our knowledge."

Baur does not now compile long range weather forecasts, but issues them only on a sporadic basis, and conducts research in that field. Research, according to an article written by Baur, is directed essentially at the

perfection of the statistical forecast relationships that were published earlier by considering factors that determine the formation of the various types of macro-synoptic conditions and furthest of all by a method of considering the role of solar activity.

According to a verification conducted by Baur [See Note] regarding the correctness of 10 day weather forecasts compiled by him during the period from 1932 to 1936, the following results were obtained;

In 1932, the correct forecasts amounted to 68% of all the forecasts, in 1933 - 81%, in 1934 - 80%, in 1935 - 87%, in 1936 - 84%. The average percentage for correct weather forecasts for those years amounted to 80%.

Different results of a verification of these same forecasts were obtained by the Americanswho verified the correctness of the forecasts for the first five days of the ten day period and the last five days of that period. Such a split type of verification was motivated by the fact that forecasts for the first five day period were compiled by means of a synoptic method and that for the second five day period was compiled on the basis of a purely statistical method. It turned out that forecasts for the first five days were correct in 75% of the cases and those for the last five day period were correct in only 53% of the cases. In order to evaluate the quality of ten day forecasts for temperature they were compared with the correctness of forecasts compiled on the basis of an assumption that the average temperature of the pending ten day period is equal to the temperature of the day that preceded the forecast period. It was found that such forecasts would have been accurate in 69.4% for temperature forecasts and 57% for precipitation forecasts. Consequently, the methodical effectiveness in temperature forecasts amounts to only 1.1% and for precipitation forecasts only 11.5%.

Baur's institute existed until 1945 and issued the 10 day forecasts indicated above. Since 1945 he, has been working privately, not receiving any kind of material support from the West German Government. He refused to regularly issue 10 day forecasts and from time to time issues only monthly and seasonal forecasts similar to those that were issued by him from 1920 to 1930. According to the indirect information that is available(Bijl W. Weers verwachtingen op lange termign, Kon. Nederl. Meteorol. Inst. De Bilt Publ., No. 137. Verspreide, Opstellen, Nr 1, Gravenhange, 1954.) The quality of these forecasts in general is not very high and not infrequently there are serious errors.

A weather service for the American Occupation Zone in Germany was established in the city of Bad Kissingen in 1946. It was headed by professor Waikman. He offered

Baur the position of Director of the long-range forecast section. In connection with that, the direction of long-range forecasts was assumed by a former co-worker of Baur's - A. Hofman. Later when the West German Meteorological Organizations merged with British, American and French zones of occupation, Denis and Trenkle also began working in the department for long-range weather forecasts. This forecasting organization which basically operated with the assistance of methods evolved by Baur did not issue ten day forecasts. Forecasts covering a month and a season were issued which, however, due to their imperfect nature, were not published but transmitted by cable to the meteorological observatories.

Starting with February, 1947, Trenkle and Rudolf began to issue and as of June 1949 to publish comparatively detailed monthly forecasts covering the south-western region of Germany from Freiburg. As of February, 1952, these forecasts were also regularly broadcast on the radio.

The verification of monthly forecasts of temperature and precipitation anamolies for the territory of the Federal Republic of Germany and that of Berlin for 1950 and 1956 compiled by the German Meteorological Service indicated the following: /See Note/ The correctness of forecasts for the summer somewhat exceeds the degree of success attained by the "blind forecast" but it is approximately at the level of inertial forecasts. The success of forecasts for the autumn and especially for the winter exceeds the correctness of the inertial forecasts by an insignificant degree. The verification of these forecasts for the same period and for the same region compiled in Washington on the basis of Namias's method indicated that their correctness during all seasons is below that for inertial forecasts.

/Note/ See an article by Hofman in Ann. Meteorol, No. 3-4, Band 8, 1957.

In 1951 in Bad Kissingen a group directed by Scherhag developed a method for forecasting three to five day trajectories and positions of centers of areas of the 24 hour decrease in surface pressure associated with the deltas of high level frontal zones.

340 sources of decreasing pressure were studied, which were observed from 1 July 1948 to 31 December 1949 over North America, the Atlantic Ocean and Europe. It was revealed that in 242 cases the areas of decreasing pressure were observed for a period of five days and 42 cases for a period of four days and 35 cases for a period of three days, whereas in 21 cases they were observed for only a period of two days. For the purpose of compiling forecasts

statistical investigation was conducted and a series of monograms were compiled that permit a determination of the future position and intensity of the initial areas of decreasing pressure for the second to the fifth day based on a consideration of the direction and the intensity of the high level frontal zone and the basic isohypse. This method is used in practice and, at the same time, research is being conducted to perfect it.

II France

As already briefly indicated in the introduction to the second part of this book, a method of forecasting based on the study of the peculiarities in the course of the pressure which are revealed in the many year curves of the five day mean of its values.

The principals of this method as well as certain other technical methods are described in the work by Grappe entitled Memorial de la Meteorologie Nazionale, n, 38, 1-78, Paris, 1953. They consist of the following:. For 82 stations in Europe and the Atlantic area new curves showing pressure changes from day to day during every year for the available period of years were compiled. Further the smoothing of every one of these curves was made by determining the sliding three or five day mean values. The comparison among these smoothed curves for a given station over all the years indicated that during certain periods of time maximums or minimums occur on the curves which take place almost every year. They are called the peculiarities in the course of pressure.

In order to eliminate accidental increases or decreases, i.e. a type of peculiarity that would frequently be encountered additional smoothing is done. For that purpose curves showing the pressure over a five year period during the course of every year are compiled for every station. Then the averaging of these curves for all the years for every station on an individual basis is accomplished. The normal curves that are obtained in that manner showing changes in the five day pressure values are called base curves or bases. It turns out that peculiarities in the course of pressure which are revealed in most of the curves (75%), were preserved in the base curve as well. However the rarely occurring secondary peculiarities were smoothed out in the basic curve.

Furthermore, the basic curves at all stations within the region and the examination were compared among themselves for the purpose of revealing those stations with an analogous course of these curves. A combination of these stations determined the region which was homogeneous

with respect to climate (natural regions). A single most representative station was selected from every one of the differientiated climatic regions and a mean curve for the entire region was drawn.

In order to prove the reality of the peculiarities and also in order to reveal their synoptic characteristics the following work was accomplished. The nature of pressure formations observed in the various climatic regions during periods when certain peculiarities appeared were studied on a basis of daily and five day charts. It appeared that for example for the Paris region in 69 to 75% of the cases during periods of rising curves anti-cyclones with a center pressure in excess of 1,020 mbs were observed. Similar investigations indicated that during periods of descending curves in a given climatic region cyclones with a pressure of from 997.4 to 1,002.7 mbs at the center are observed. Their recurrence amounts to from 76 to 86%.

These peculiarities noted in the curves for every station in each individual year were also thoroughly studied and these shifts (with relation to the normal curve in the moment of their occurrence were determined. It turned out that for the Paris region the average shifts in the upper points of the peculiarities took place within two to four days in cases of their early appearance and three to 4.6 days in cases of late appearance.

A series of synoptic characteristics were compiled for every one of the periods of time when a certain peculiarity was observed: a mean chart (normal) of surface pressure, a cumulative chart showing the distribution of cyclonic and anti-cyclonic centers, a chart showing the distribution of the amplitudes of pressure curves, a graph showing the recurrence of the shifts in the moment of their occurrences, as well as the characteristics of air masses and their temperatures. All this data taken together permits the compilation of forecasts for the distribution of the pressure field and certain weather characteristics for a period of five days, and sometimes for a period of 30 days.

In order to make the five day forecasts more detailed the relationship between mean pressure values for the five day period with its values during the day in the middle of the period was studied. It was revealed that this relationship is expressed rather well (the correlation coefficient is equal to +0.88) [See Note]. A significant relationship was also obtained with the data of the second and fourth days. Coefficients for the first day and the last day are considerably lower;

for the first day 0.55-0.79 and with the fifth day 0.63-0.80.

[Note] A similar relationship was obtained by Namias. It was mentioned in section two of chapter 11.

A forecast for the mein pressure field for the five day period is compiled in the following manner. A curve showing the change in five day pressure values for a number of five day periods preceding the forecast for every one of the 82 stations. Then this curve is compared with the basic curve for a given station, peculiarities are found and matched then by means of a relative shift of these curves. After finding well matched peculiarities closest to the five day periodcovered by the forecast the pressure curve is extrapolated and the anticipated pressure change is determined from the initial five day period to the one covered by the forecast. By algebraically adding this change to the pressure value at a given station that occurred during the initial five day period its prognostic value is obtained. Pressure for the other 81 stations in the region being examined is also forecast in this manner. A prognostic isobaric map is drawn on the basis of this data.

Later by utilizing the synoptic and statistical material as indicated above as well as the daily it is attempted to make this forecast more detailed for the individual days and to point out the probable nature of the weather and its changes during the five day periodcovered by this forecast.

At the same time attempts were made to consider the intensity of the processes as well by refining the forecast for the variation amplitude in the pressure curves. For that purpose the results of investigations on the evolution of centers of pressure changes from a five day period to a five day period (charts of five day isallobars) are utilized.

Forecasts prepared according to the methods described above are compiled daily at the central weather service in Paris for a period of five days in advance.

Starting with 1951 forecasts for a month ahead are prepared by means of this method. They are based on an extrapolation of pressure according to base curves of a number of stations. The month covered by the forecast is divided into six or seven periods of time during the course of which a certain type of weather is observed. Average isobaric charts are drawn for such periods. Such charts are able to provide an indication on the probable weather comditions during each such period. This data is then made more precise and concrete by utilizing a series of synoptic, statistical and graphic material.

As a result a forecast covering a month is compiled which provides a general characteristic of the anticipated types of processes (pressure field) and the evolution of weather conditions during the month.

We unfortunately do not have data on the methodical and practical effectiveness of the methods that were examined, in the monograph that was available to us. However, it is hardly possible to consider this method perspective. Despite the existing investigations on the synoptic characteristics of the peculiarities the pressure field may still not evenly reflect the type of weather.

A concrete deficiency in this case is also the fact that up until the present time the physical causes for the occurrence of the peculiarities (rhythms) indicated above in the changes of pressure have not been revealed. Therefore the utilization of pressure curves and the entire technique of such a forecast appears to be to a great degree formal. Multilateral investigations of the regularities in the uninterrupted development of the macroprocesses over prolonged periods of time are necessary. Then the revealed peculiarities may be explained to a degree inasmuch as they may be regarded as certain stages in the development of macroprocesses.

At the same time, it is necessary to note a certain scientific and prognostic value of the data obtained by this school. The existance of such data for other regions of the hemisphere could in a number of cases prove to be a very useful and helpful method that would permit the forecast of certain peculiarities in the development of anticipated (on the basis of any method) processes in weather conditions.

III. The Chinese People's Republic Work in the field of long-range weather forecasting started in 1935 with the work of T'u Ch'ang-wang who utilized the corelation method developed by Walker to reveal the associations between precipitations in China and changes in the meteorological elements at a number of points on the earth's surface.

Two statistical methods of forecasting are developed in the Chinese People's Republic: A method of historical changes and a method of multiple internal relationships. The first of these methods was developed by Yang Chiang-ch'u and the second method was developed by Fang T'ung-kwang. Let us examine these two methods in greater detail.

A chinese scientist, co-worker in the institute of geophysics of the chinese academy of sciences, Yang Chiang-ch'u in 1950 proposed that for forecasts of temperature and precipitation in Peking as well as for forecasts of typhoons in the Formosa region a series of regularities

and historic changes of these elements and phenomena be used.

The proposed method was applied by the author in practice, for the compilation of the indicated forecasts. It yielded satisfactory practical results. It was also examined and approved by the Peking section of the Chinese Meteorological Society at a session that took place on 23 October 1951, and was recommended for a practical test and utilization as a method that has a number of advantages under present day conditions in China.

A comparatively extensive series of observations are available at certain stations in China. Therefore the author confronted himself with the task of elaborating a method of forecasting for these stations which was based on the utilization of regularities in the changes among meteorological elements over a long period of time only for these stations. Such changes that took place over several decades are called historical by the author.

The basis for such a presentation of the task is visualized by the author in the fact that the observed historical changes in meteorological elements are a consequence of cumulative influence of the active factors. Therefore, considering the indicated changes we will thereby indirectly consider the entire complex of factors. Therefore in order to be able to foresee changes in the future it is necessary to reveal regularities in the changes of the elements during the past. Let us now examine some of the basic regularities.

Regularities in historical changes utilized in compiling forecasts. The basic rules of historical changes which must be considered in the compilation of forecasts for a year are:

(1) The continuity,
(2) the analogy,
(3) the cyclic nature,
(4) the greatest and the least probability,
(5) the turning point.

Let us now examine each one of these laws.

Continuity. By continuity the author means the duration of the noted tendency in the change of a given element or phenomena. Let us assume for example that we are analysing a many year curve showing changes in temperature of the air for some station. After finding all points on this curve where it begins to rise we shall trace the duration of this rise. Let us assume that in all cases the observed increase in temperature continued for no less than two years. In that case having recorded the rise in temperature during the initial year with regard to the year covered by the forecast as compared with the preceding

year we will be able to assert with a great degree of certainty that there will be rise in temperature here during the next year. The author illustrates this law by an examination of the curve showing the many year course of changes in the amount of precipitation at Peking during May for the period from 1840 to 1855, and from 1870 to 1950.

As a result of a revelation of the continuity the following prognostically important deductions are established.

(a) If the amount of precipitation during May of a certain year exceeded 40 mm, while in May of the next year it was less than that, then during May of the third year it always decreased further, or in any case, did not rise. There were no exceptions to this.

(b) If the decrease in the amount of precipitation occurred during the course of two years (in May), then during May of the third year no increase in precipitation was observed, and in 80 to 90% of the cases it amounted to an average of 33 mm.

Analysing the changes in the velocity of the circular westerly current in December in the zone between 35 and 55 degrees northern latitude, for the period from 1900 to 1930, the author illustrates a law of continuity by means of the following deductions:

(a) If in December of a certain year, the circular westerly current began to intensify or did not weaken then for the next year the intensification continued. This was the case in six out of seven instances.

(b) If the velocity of the current began to diminish during December of a certain year then during the following years as a rule it continued to lose its velocity or, at any rate, the current velocity did not increase. This was the case in five out of seven instances.

The analogy. Analogy is understood to be the similarity in the course of the curves in different sections. The utilization of analogies is recommended along with the feature of continuity. In that case it may not only be a valuable prognostic measure, but it may help to avoid errors in the forecast that may arise due to exceptions in the continuity rule. The continuity rule may in turn refine a forecast compiled by utilizing the principal of analogies especially in those cases where the analogues processes that occurred in the past will be followed by different processes in the future.

The cyclic nature. The author notes that the numerous investigations aimed at revealing various cycles did not yield prognostically useful deductions inasmuch

as the authors of these investigations always demanded presence of constant limits for these cycles and considered their recurrence mandatory. Under actual conditions however, cycles of quite different duration are observed which in addition to that may not be observed at all during certain periods of time. It therefore follows that if the cyclic nature is regarded not as the only means for forecasting but is applied in combination with the other rules (continuity, analogy) than it may be of concrete aid in the compilation of long-range forecasts.

There is a considerable difference between the cyclic nature and analogy. A complete cycle may include analogous features, however an analogy itself is not equivilant to the cyclic nature. Analogy indicates that changes taking place in any two sections are similar among themselves. However, it is not necessary that an analogy occur only at certain regular intervals of time.

In order to illustrate the cyclic nature we will cite the following regularities which have a prognostic significance.

(a) A curve showing the many year course of mean annual velocity values of the circular current of the westerly wind indicates a maximum point every five years (1903, 1908 etc.,) and every four years (1901, 1905, 1909) the minimum point.

(b) The curve showing changes in winter temperature in Shanghai for a period of 75 years (1873 to 1948) clearly manifests two year cycles. They include over 80% of the years. In other words, the winter temperature in Shanghai as a rule rises during one year and drops during the next year. This cycle is especially well expressed between 1882 and 1908 at which time exceptions were not observed.

(c) The curves showing many year changes in the amount of precipitation at Mukden (1906-1936) clearly indicates that every six years there is invariably a minimum amount of precipitation of 100 mm or less.

The greatest and the least probability. This aspect presupposes a multilateral analysis of the recurrence of various values of a given element over a period of many years. A knowledge of the probability regarding the occurrence of the forecast value or of a gradation of an element is most important to a forecaster. In analysing, for example, the amount of precipitation which occurred in Mukden during July it is possibleto see that it never exceeded 300 mm. This level of precipitation was observed on only one occasion. At the same time a precipitation level of 30 mm was never observed here in July. Consequently, the probability of

precipitation over 300 mm and below 30 mm is very small.

The turning point. This term is understood to mean the time when a changing tendency which took place during a certain period of time such as a rising or dropping curve changes its direction. If the time of change of direction in the many year tendency occurs during the year covered by the forecast that may then materially change the nature of the forecast and influence the degree of accuracy if the indicated peculiarity is not taken into consideration in the compilation of the forecast. Forecast of the turning point is one of the most complex and unresolved aspects of the forecast method under examination.

The application of this method of forecasting requires the availability of observations for a minimum period of 20 to 30 years.

The basic stages of analysis in forecasting consists of the following:

(1) The available observation data is prepared. For that purpose charts showing mean monthly values are plotted data pertaining to the recurrence of various values of meteorological elements being examined is compiled. Curves depicting historical changes in elements are drawn on graph plotting paper.

(2) Curves showing historical changes are analysed for the purpose of revealing prognostic dependencies that characterize the basic laws examined above. The resulting prognostic dependencies are noted. Periods of time when any one of the basic laws has an exception are established. How this incongruence with the basic law may be corrected by the application of some other law. The turning points are analysed in this special manner, the course of the curves preceding those points, as well as those following these turning points, are revealed in addition to the conditions under which they occur.

(3) By utilizing the regularities obtained from an analysis of the historical changes a forecast for the following year is compiled.

The examined approach to the compilation of extra long-range forecasts has certain advantages over other methods under the conditions existing in China, where there are no synoptic charts for a large number of years. The basic advantages are as follows:

(a) The extensive periods of the forecasts (a year and sometimes even two years)

(b) The simplicity of the method of compiling the forecast,

(c) the forecast contains quantitative character-

istics which is more convenient in practice than formulations above or below the norm, much higher or insignificantly higher which are used in certain forecasts (the author in particular compares them with forecasts prepared by Baur for a period of ten days),

(d) the given method may be applied for forecasting any meteorological element or phenomena on which there is a series of observations for a period of not less than twenty to thirty years.

(e) A multilateral analysis of the regime (climatological)data is conducted and the positive results of the practical application of them are demonstrated. All this indicates the important significance of the consideration of processes that preceded the forecast and the regularities inherent in the tendencies of their development over a period of many years.

Along with these positive points, the existing inadequacies may also be noted, the most important one from our point of view is, that the many year changes in meteorological elements are examined independently of the many year changes in atmospheric circulation, which may be used to explain regularities established by it.

The work does not even make an attempt to analyse the physical reasons that determine the action of the established laws and the causes for the presence of exceptions in their application.

Therefore, it seems to us that in the further development of this method it is necessary first of all to establish such relationships with the atmospheric circulation and with its concrete forms. The W, C and E Forms may be used as the latter the irregularities in the epochal transformations of which are, at the present time, fairly well known (see chapter V).

The feasibility of utilizing the W, C and E Forms for the indicated purpose is favored by us also as a result of the positive results obtained by the work accomplished by post-graduate students at the Leningrad hydrometeorological institute, Chang Chi-chia and Chang Chia-ch'eng who completed (under the guidance of the author of this book) investigations one of which was published under the title of "Peculiarities in Weather Conditions over China Under Basic Forms of Atmospheric Circulation" and who obtained some very valuable results in a scientific and prognostic sense.

These works conclusively prove that weather conditions observed over China during various seasons of the year, are well explained by the W,C and E Forms, and of their seasonal transformations. Therefore, the authors utilized such relationships for the elaboration of a method of forecasting

both for long and short periods of time applicable to the conditions existing in China.

These works also examine epochal transformations of the W, C and E Forms and the associated temperature changes, changes in the amount of precipitation, and the fluctuation in the levels of the Yangtze and the Hwangho Rivers.

Let us now briefly examine the basic contentions of the second method used at the present time in the Chinese People's Republic. This method is based on the utilization of the analogues selected on the basis of climatic data for several preceding months. It permits a compilation of a forecast for a period of up to a year. Let us illustrate it in any example of compiling a forecast in February of 1953 for precipitation during August 1953 for the city of Chungking.

The amount of precipitation observed during individual months of the preceding (1952) year were analysed. At that time a survey was conducted for a period of time during which in the course of several months entering into such a period some kind of a material peculiarity in the distribution of precipitation was observed which could serve as a point of reference in the selection of analogues. In the example being examined the amount of precipitation in Chungking during a period of three consecutive months (October, November, December 1952) was close to the norm, while in the next month of January 1953, it somewhat exceeded the norm. Taking this peculiarity as a basis attempts are made to find analogues among preceding years. The amount of precipitation in every month of all the analogues are reviewed following the month with the indicated initial condition (first month, second month, and so on).

In our case, it was proven that the amount of precipitation during the eighth month for most of the analogues was below the norm for a period of many years. Further the amount of precipitation for the eighth month which was covered by the forecast, was studied and a comparison of it with the amount of precipitation during the preceding month was conducted. As a result of this analysis a highly accurate forecast was compiled.

According to the available data, forecasts for temperature and precipitation anomalies compiled on the basis of the indicated methods have an average certainty of 75%. Forecasts regarding the magnitude of the anomalies have a somewhat lower percentage of certainty.

In evaluating these methods it is possible to agree with Ch'an Nei-ch'ao that "both methods serve only for the satisfaction of the more urgent demands. Both methods possess serious inadequacies. By means of these methods it is especially difficult to forecast the extreme values of the

meteorological elements as both methods are devoid of any physical basis. In addition to that for a practical utilization of these methods it is necessary to have a large number of initial data. It must also be noted that the quality of these methods up to the present time was not investigated on the basis of strict methods of mathematical statistics. Such an investigation is outlined for the future".

IV. Hungarian People's Republic.

Investigations in the area of long range weather forecasts began in Hungary in 1939. In 1946 a department of long range forecasts for weather was organized at the institute of meteorology at Budapest which issues forecasts for two week periods regularly on the 15th and the 30th of every month. The forecast includes expected weather changes during the period covered by the forecast as well as anomalies in the temperature of the air and the amount of precipitation.

The forecast method is based on the utilization of statistical relationships between changes in meteorological elements and phenomena on the one hand and a series of geophysical and cosmic factors on the other. In addition to that various types of periods and changes in the cycles of meteorological elements established by different authors are used.

The number of investigations which obtained various forms of prognostic deductions must first of all include the work accomplished by Berkes completed in 1939. It indicated that after an increase in solar activity a decrease in the wind velocity follows approximately a week later in Budapest, in connection with anti-cyclonic nature of weather over Hungary. A week after the solar activity begins to diminish, a period where the wind velocity increases associated with the development of cyclonic activity appears. Consequently, having a forecast of a change in solar activity it is possible to forecast the course of the wind and the nature of synoptic processes for a period of two weeks in advance.

Investigation was completed later, which attempted to determine the probability for the appearance of positive and negative temperature and precipitation anomalies in Hungary under different two week variations in solar activity. The values of the resulting probabilities exceed the change values by 5 to 15%. These relationships indicate that if the number of solar spots increases during the weeks immediately preceding the summer and winter seasons, then it is proper to expect a winter and summer temperature below norm in Budapest. This relationship is especially well expressed during January June and July. As far as the precipitation is concerned, with an increase in solar activity the amount of precipitation dur-

ing the winter is below norm and that during the summer is above norm.

Beginning with 1942 the prognostic relationships indicated above were supplemented with relationships between changes in the weather characteristics and phases of the moon.

In compiling forecasts, the results yielded by work on the study of cycles are also used. Some of the better verified and more widely used cycles are the 11-summer, 2-3-summer, the sixty day cycle and the 335 day cycle.

Analogues also provide concrete help in the compilation of forecasts.

The correctness of two week forecasts prepared on the basis of the relationships examined above amounts to approximately an average of 70%. Some of the better forecasts sometimes had a correctness value of up to 90% and some of the poor forecasts - 30%. In this case the correctness of the forecasts for weather changes is higher than the forecasts for temperature and precipitation anomalies.

In future investigations it is proposed to conduct a more substantial study of the relationship between regeneration of the Azores anti-cyclone whose state in many respects predetermines the weather conditions over Hungary, with solar activity. The relationships that have already been established between the intrusion of anti-cyclones from the Arctic and the intensification of corpuscular radiation of the sun will be developed further, as "even though the formation of the weather characteristics depend only on the influence of various factors which have a terrestrial origin we nevertheless recognize the fact that a considerable role may be performed also by comparatively energetically weak factors of cosmic origin in the form of catalytic agents during the incubation of various weather-forming processes." /See note/

/Note/ Berkes Z., Acta Agronomica, V, No. 1-2, 163-186, 1955.

From the above brief survey it follows that in Hungary, even though a regular compilation of forecast is conducted, the methods for their compilation, however, may not be considered complex, perfected and responsive to the contemporary state of our knowledge on the general circulation of the atmosphere. In particular, all forecasts are compiled only on the consideration of the cosmic factors and formal statistical associations as well as on the consideration of cycles and periods that do not yet have a physical explanation.

Scientists that are occupied with this problem in Hungary understand that the given method is not as good as the synoptic and circulation methods that are used at the present time in other countries of the world. Extensive material consisting of high level and surface observations

from the entire hemisphere however are necessary for the utilization of such methods, which complicates the application of these methods in the comparatively small countries such as Hungary.

V. The Roumanian Peoples Republic.

Systematic investigations in the problem of long range forecasting of the weather began in Romania in 1951. They are primarily concentrated at the central meteorological institute located at Bucharest.

The following principals underlie these investigations /See note/

(1) the weather characteristics for any given month or season are determined on the basis of its characteristics during the preceding month or season when quantitative accumulations of peculiarities take place which in turn lead to qualitative changes in the circulation and the weather in the subsequent month or season;

(2) Pressure and thermal fields, the distribution of precipitation and the characteristics of the circulation are an inseparable entity and must be examined simultaneously and jointly;

(3) In order to properly comprehend their interrelationship and to have a possibility of forecasting their characteristics for the future, it is necessary to consider the role of solar activity, the phases of the moon and the large planets closest to the earth.

/Note/ Topor, N., Acta Agranomica, 1955, No. 1-2, 163-186, 1955.

Both the normal distribution of the indicated elements over Romania and their distribution over the surrounding regions (the Azores, maximum, the Icelandic, minimum, the Siberian, maximum, and other action centers) as well as the large scale anomalies were studied on the basis of these principals. The latter question received special attention in view of its extensive national economic significance.

Basic material used for conducting the investigations were diurnal synoptic charts for the period from 1886-1951. The first stage of the investigation established the types of pressure fields over Europe and their peculiar weather conditions over Romania and over southeastern Europe as a whole. It was found that there were only 16 such types. Subsequently the probability for the appearance of every type for every day, month, and season was computed.

After that a macrosynoptic investigation was conducted, as a result of which the 16 types of pressure fields indicated above were included in 7 types of circulation and observed in south-eastern Europe; the northern continental, the southern continental, the eastern continental, the southeastern maritime, western oceanic, and the northwestern oceanic.

The recurrence of every type for all months of the year was computed (in percentages and days).

The analysis of these types permitted a determination of the following relationships which have a prognostic significance:

(1) A sharply increased probability for the occurrence of a certain type of a pressure field or of a certain type of circulation is noted at a given time of year and during individual days of every month. For instance the first type of pressure field has its greatest rate of recurrance during February (16.3%). During every month it is most probable on the following days; January - 4,10,11,13,20, February - 2,4,10to11 21, March - 1 to 2, 8 to 9, 17, 26, etc.

(2) The type of pressure field or a type of circulation that became established during a given season will recur again during the same season after 28 to 32 days.

(3) The intensity of individual types of pressure fields increase during the period from 20 August to 20 March and gradually diminish from 20 March to 20 August.

(4) The degree of differentiation of the various types of pressure fields as well as the intra-monthly changes in the types of circulation is variously expressed during the maximum and minimum periods of solar activity.

(5) The thirty day cycle in the course of atmospheric pressure in central Europe is associated with phases of the moon. /See Note/

/Note/ Topor, N., Acta Agranomica, 1955, No. 1-2, 163-186, 1955.

In accordance with the plan of investigations it is proposed to conduct a typification of temperature fields, precipitation and other meteorological elements and phenomena in the future. At the same time special attention will be devoted to "a more detailed investigation in the field of the general circulation of the atmosphere". /See Note/

/Note/ Topor, N., Acta Agranomica, 1955, No. 1-2, 163-186, 1955.

From the above it follows that in Romania investigations in the problem under examination here are at a very early stage of development considerably removed from the establishment of a method for long range weather forecasting. As far as the basic principals on which these investigations are based are concerned it is possible to agree with their correctness and perspectiveness, inasmuch as they confront themselves with a goal of conducting a thorough study of meteorological elements over Romania in connection with deveopment of the general sirculation of the atmosphere. However the aspiration to establish associations between changes in atmospheric processes with phases of the moon appear to lack perspective. The influence exerted by the small and cold

moon, even though it is the body closest to the earth, is apparently limited to the phenomena of tides in the external surfaces of the globe and cannot have an effect on the characteristics of atmospheric processes.

VI. India

Investigations in the area of long range weather forecasting started in India after 1877, a year that was known for its exceptional drought and famine in that country. In India the forecasting of the amount of precipitation which occurs during the monsoon season (from June to September) is of basic significance. The correct forecast of a deficit in precipitation is especially important as obviously poor harvests in the country or in its various regions are associated with such conditions.

In connection with this Blenford utilizing the "world weather" method established the task of revealing factors that determine the small amount of precipitation during the monsoon season in India. He established that the droughts were preceded by an anamously heavily snow fall during the winter and spring in the mountains located to the north and north west of India (the Himalayan Range and the Hindu-Kusch upland area) as well as high pressure on the Island of Mavrikiya, in Australia and over a considerable portion of Asia.

Forecasts for rain for the period from 1886 to 1901 were compiled with the aid of these relationships and received the recognition and trust of the public. From 1887 to 1903 however when the weather forecast service in India was directed by J. Elliot, who began issue and publish greatly detailed forecasts without a sufficient background for that, these forecasts lost their practical significance. As a result of that the government of India prohibited official publication of these forecasts in 1901 and authorized their utilization only by the provincial adminstrations.

A well-known British climatologist, Walker, worked in India since 1903. He headed the further investigations in this problem. They amounted to a survey for statistical relationships between the amount of precipitation in India during the period from June to September and the state of certain weather characteristics in various regions of the earth during the preceding period. As a result he evolved a series of regression equation of the common type

$$y = aX_1 + bX_2 + cX_3 + dX_4 + eX_5$$

where y-is the forecast volume of precipitation in India, $X_1 X_2 X_3 X_4 X_5$- are various elements associated with precipitation a, b, c, d, e, - are constant coefficients with which the equation yields a closer approximation to reality with respect to the amount of precipitation.

For instance, in one such equation (for the northwestern region of India) X means the amount of precipitation in Southern Rhodesia during the preceding months (from October to April inclusive), X - is air pressure in South America, X - is temperature of the air at Dutch Harbor(situated in the Aleutian Islands) during the preceding months of March and April, X - is a main pressure at the equator for February and March, X - is the general altitude of snow cover in the western part of the Himalayas during the preceding month of May.

Analogous regression equations were prepared for other regions of India as well, where other factors are included and some of the ones ennumerated above are preserved. The verification of these equations on the basis of material for the past years (from 1909 to 1928) was conducted by Charles Normand in 1930 (he succeeded Walker). The correlation co-efficient between the precalculated and the observed amount of precipitation was plus 0.56. It is close to the co-efficient which was established (plus 0.58) on the basis of data covering the period prior to 1908.

In connection with the results of this verification it was decided not to publish in advance those forecasts which provide information on values close to the norm. Only those forecasts which contained significant deviations in the amount of precipitation from the normwere subject to publication. During the period from 1941 to 1948 70 such forecasts were released fo. various regions in India, 13 of which (i.e. approximately 20%) proved to be incorrect. If climatological forecasts (i.e. norm) would have been provided then there would have been only 27 incorrect forecasts, i.e. approximately 40% of all the forecasts.

It must be noted however that despite the general positive effect, forecasts of extreme droughts have a low degree of accuracy. For example out of nine such forecasts for very dry years (1937-1938, 1939, 1941, 1951,1952) only three forecasts were correct, and it is these droughts that are destructive.

In connection with this, substantial investigations of the synoptic nature of monsoons (see paragraph 4 of section 2 of chapter II for more details) were conducted in India over the past several years for the purpose of demonstrating the relationship between the types of processes over India and various peculiarities of the general circulation of the atmosphere in other zones of the earth, and, specifically, that with the position and shift of tropospheric waves in the westerly currents of the moderate latitudes with the currents, disturbances in the zone of the equatorial trough and others.

There is basis to suppose that this type of investigations will permit the establishment of not only the physical nature of various factors entering into the regression

equation but to reveal new factors as well. All of this together will, undoubtedly, considerably develop the method and will raise the quality of the forecasts for monsoon precipitation.

VII Indonesia

In Indonesia like in India, the greatest practical interest is represented by forecasts of precipitation during the eastern monsoons.

Investigations of this problem started in Indonesia in 1908, when C. Braak started to study the relationship between pressure changes and the amount of precipitation. /See Note/ In doing so, the author based himself on the fact: If during the monsoon period the pressure is below normal, then the amount of precipitation must exceed the norm, and in the opposite case the precipitation would be below normal /Note/ Braak, C., Berlage, H. P., Boer, H. J., Euwe, W., Reesinck, J.M., Verhandelingen No 5, 20, 26, 29, 30, 31, 32, 35, 36, 38, 39, 44 van het Koninklyk Magnetisch en Meteorologisch Observatorium te Batavia, 1919-1952. The forecasts compiled on the basis of this rule for 1909 and 1910 had a good rate of accuracy. This compelled a more detailed study of the indicated problem. As a result, a three year periodicity in the changes of pressure was established and three rules for forecasting pressure were formulated.

However even these perfections did not prevent a catastrophic forecast failure for 1925, when it was forecast that the amount of precipitation will only slightly exceed the norm, whereas actual conditions resulted in a drought that was never observed before.

Braak's work was continued by Berlage (Verhandelingen van het Koninklyk Magnetisch en Meteorologisch Observatorium te Batavia). He was especially engaged in finding a relationship between the amount of precipitation during the eastern monsoon on Java and a deviation of temperature and pressure from the norm at various regions of the Indian and Pacific Oceans during the preceding months. He also considered the role of solar activity. The regression equation that was derived yielded positive results prior to 1925. Later However, the quality of the forecasts deteriorated sharply as the physical nature of the relationships that he established remained unclear.

A certain perfection of the regression equations was conducted by Boer. As a result, by using them it was possible to predict on 1 September the early advent or the tardiness of the normal rains of the monsoon period in terms of 10 day periods. Similar investigation for the forecast of precipitation in the region of Java, Madura, the Islands of Celebes and Borneo were conducted by Euwe.

Even though such relationships do represent a certain practical interest, "they nevertheless brought but a few indubitable successes". The reason for these failures according to Reesin,C.K.,is partially due to the fact that the researchers had at their disposal a very limited series of observations and therefore the co-efficients and equations calculated by them may not be considered reliable.

VIII The Netherlands

The first attempt to evolve a method for long range forecasting of air temperature for the forthcoming winter in the Netherlands was accomplished by Galle during the First World War. He established a relationship (on materials covering the period from 1900 to 1914) between the force of the northeast trade wind observed north of the equator during the summer months,and the subsequent air temperature in Europe in the winter. The presence of this relationship was motivated by the fact that the northeastern trade wind was the basic reason for the change in the velocity and the temperature of the gulf stream and, through it the air temperature in Europe (See Paragraph 2 of section 2 of Chapter II).

By utilizing this relationship Galle compiled forecasts of the mean temperature in Europe for the winter of 1915-1916, which had a comparatively high degree of accuracy. However, the success of subsequent forecasts was rather middling. In addition to that the verification of this relationship on the basis of a new series (prior to 1930) indicated an almost complete lack of success.

Later investigations in the indicated problem were directed by Braak. The results of these investigations were published in 1933. In studying the relationship between solar activity and the amount of precipitation in the Netherlands, Braak established that " as arule the predominant majority of precipitation occurs during a period which extends from a time when there is a maximum number of sun spots to a time where a minimum number of sun spots are evident. After the time when there are a maximum number of sun spots a drier period,with a minimum of rain,comes about between the maximum and minimum evidence of sun spots". However, verification of these rules in prognostic work indicated their extremely low effectiveness.

Subsequently, Reytsma, Visser and Berlage worked on the given problem at various times. They based themselves on a consideration of the periodicity in changes of meteorological elements, and also evolved various types of statistical relationships and regression equations. For example, the temperature of the air at DeBilte and the average amount of precipitation throughout was correlated with 18

elements at different parts of the world. Among them were the air pressure at the Azores Islands, the difference between the pressure at the Azores Islands and Iceland, the water level in the Nile River, the temperature on the Yan-Mayen and others. The regression equations were compiled for forecasting temperature and precipitation for a period of from one to three months in advance.

At first the forecasts compiled on the basis of these equations were considerably successful. However, their subsequent correctness became rather low. As a result of this the authors came to the conclusion (Baijl W. Weers, Verwachtingen op Lange Termijn, (Kon. Nederl. Meteorol Inst. DeBilt, Publ., No 137.) but it was impossible to successfully resolve the problem of forecasting not only for the Netherlands but for other countries of the world as well by this method. It is rather difficult not to agree with this deduction.

IX. Japan

According to the available information forecasts in Japan are compiled for ten day periods with detailed information for each day, forecasts are also compiled for periods covering a month with detailed information provided on the basis of ten day periods, the forecasts covering periods of a month included detailed information on a basis of ten day periods, the forecasts for three month periods contained details on a monthly basis; forecasts were also issued for six month periods.

Methodical elaborations utilized in the compilation of such forecasts are based on a consideration of the periodicity and changes in meteorological elements as well as on a formal extrapolation of data at a single point. Usually, at first, the deviations from average values of pressure and temperature for the preceding periods of five days duration are determined. Then these deviations are extrapolated with the aid of periodicities of 20, 25, 35, 45, and 65 days.

A verification of the correctness of forecasts for the period from February to October 1952 was conducted. It was revealed that the temperature forecasts were correct in 70% of the cases whereas the correctness of pressure forecasts were correct in slightly more than 50% of the cases. Forecasts of precipitation, however, proved to be completely unsatisfactory.

X. England

In England there was a extremely skeptical attitude towards the possibility of successful compilation of long range weather forecasts. The prevalent point of view on this problem was expressed by Robert Watt who, in June of 1952, at the Conference on Problems of Industrial Natural Sciences, stated as follows:

"at the present time, forecasts covering 24 hour periods are the most reliable. Under ideal conditions, for example, when stable weather conditions are observed it is possible to compile and publish forecasts covering a period of 3 days. A forecast covering a 5 day period is a dream and in order to compile a forecast covering a 5 week period, it is already necessary to revert to average climatic values".

The prevalence of such a viewpoint regarding this problem is apparently the reason why regular long-range weather forecasts are not issued in England. The English meteorological institute conducts a discussion of forecasts for the subsequent 4 days twice a week on a experimental basis. These forecasts are published only in exceptional cases. The methodical basis for these forecasts is founded on "a theory of development", proposed by Sutcliffe /See Note/. It is based on a consideration of the dependence between the thermal wind established on the basis of a 500 to 1000 mb chart and the development and shift of pressure formations close to the surface of the earth.

/Note/ Sutcliffe, R. C., "Quarterly Journal of the Royal Meteorological Society", 86, 1956.

Even though the interrelationships that were derived are faithful in general only for a forecast covering a 24 hour period under certain circumstances they may be utilized for a forecast covering a 3 to 4 day period. In that case the prognostic charts for the first day are the initial charts for the compilation of the forecast for the second day and so on.

Methods used in other countries are not utilized in England since, according to the opinion of many meteorologists, the country occupies a most unfavorable geographical position for that purpose and therefore the regularities obtained for other territories may not be effectively be applied here.

CONCLUSION

The material that was presented in the first and second parts of this book permits the certification of the material progress that has occurred in the study of the general circulation of the atmosphere over the past 15 to 20 years.

A direct result of that is the fact that by the present time a series of new methods for long-range weather forecasting have been developed which are founded on the regularities of the general circulation of the atmosphere and which provide the opportunity to compile more perfect forecasts then was possible under the former methods based on regional associations or on other associations of a statistical nature.

This not only provides the opportunity to properly outline a path for further investigations in such important and closely interrelated problems, but it also inculcates certain hopes for the possibility of a substantial increase in the quality of long-range weather forecasts in the very near future. An especially important contribution towards the solution of the indicated problems was made by Soviet scientists. In our country hydrodynamic methods are also developed along with the comparatively effective synoptic methods.

International cooperation among the meteorologists is also of essential significance to the solution of these problems. A wonderful example of such cooperation is the International Geophysical Year (IGY), which permitted the collection of many simultaneous complex observations over the entire globe that are extremely necessary for a substantial extension of our knowledge of the regularities inherent in the general circulation of the atmosphere. In this case, an invaluable contribution was made by Soviet scientists who provided the opportunity to study the atmosphere of the earth and the planets with the aid of new methods, specifically sputniks, as well as meteorological and cosmic rockets.

A further international exchange of materials and experience gained by the scientists will be most beneficial.

The primary tasks involved in the further investigations in the indicated problems, according to the author, are as follows:

1) A multilateral full-scale study of the regularities in the changes of characteristics inherent in the general circulation of the atmosphere over the surface of the earth and the associated peculiarities of the circulation and weather conditions in its various regions. At the same time, it is necessary to bear in mind that regularities in synoptic processes that are observed in small regions may be properly comprehended only in cases where they are studied against a background of processes in the general circulation which conditions them in many respects. The study of such regional processes independently of processes taking place in other regions of the globe provides only a possibility to classify them and does not permit a revelation of regularities inherent in the changes of various types of processes. In such a case, the investigation provides little that is of value in a prognostic sense. The aerosynoptic investigations in this case must be closely associated with mathematical investigations in order to formulate a complete theory on the general circulation of the atmosphere and a theory of concrete methods for long-range weather forecasts.

2) A multilateral study of factors that are already known (see chapter 2) that determine the nature of the general circulation of the atmosphere and the establishment of new heretofore unknown factors. In this case, in addition to the revelation of a physical essence of all the factors, it is necessary to devote special attention to their role and to the change of such a physical essence in time.

3) A Study of small scale processes the regularities of which form a basis for extended weather forecasting against a background of larger scale processes the regularities of which in turn form the basis for long-range weather forecasts. In that case forecast methods for forecasts of a long-range and extended nature will be formed on unified principles and will supplement each other in the prognostic work.

4) A study of the nature of the anomalies

in the development of the general circulation of the atmosphere and the associated anomalies of the weather conditions in the various regions of the globe.

5) A study of the regularities inherent in oscillations of the general circulation of the atmosphere taking place over many years and the related changes in the atmosphere and the hydrosphere. The knowledge of such regularities will permit not only to improve the quality of the methods of extended hydrometeorological forecasts but will also provide the possibility to extend them to cover a period of up to a year, or several years, i.e. it will permit an approach to the solution of the problem of extra long-range forecasts.

6) A study of the peculiarities of atmospheric circulation in artificially created models of our planet and the verification of the resulting regularities under natural conditions by the establishment of corresponding complex observations.

7) The organization of systematic simultaneous observations (similar to those which were conducted according to the IGY Program) throughout the world which yield an understanding of the constant changes in time of all the active factors of terrestrial and cosmic origin. It is necessary that these observations be immediately processed at an international center, published and transmitted to all scientific meteorological institutions of the world for further study.

8) A rational utilization of efforts and financial expenses of the various countries for meteorological research in order to accelerate and perfect the collection and processing of primary materials. At the same time, it is necessary to bear in mind that the rational distribution of weather stations over the globe and the nature of observations carried out by them, at the present time has an incomparably greater significance for science than an increase in the density of the net in isolated regions and countries limited in area.

9) A wide-spread utilization of electronic computers and other new technical means suitable for the analysis and observations of the necessary type and accuracy.

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